DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

EEL-4920 – SENIOR DESIGN I

Fall 2022

Autonomous Lawn Mower

TEAM 16

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SENIOR DESIGN II PROPOSAL

Submitted to: Professor Wilmer Arellano

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Mentor Signature: See Appendix C

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Acknowledgment

Team 16 would like to formally thank Dr. Gustavo Roig for everything he has provided for in concern to our project. Throughout the semester Dr. Roig has provided advice for our group to further improve the design of our project. Dr. Roig was able to provide insight into the process and inspire us to create the sensors and doghouse for the project. Lastly, the team will like to acknowledge Professor Wilmer Arellano for his guidance in Senior Design 1, for us the lessons that you have taught us have been the reason we can accomplish all that we have done so far. Professor Wilmer Arellano gave us all the tools needed for our project to be as successful as it is.

Abstract

The final proposal discusses the research and development of the Autonomous Lawn Mower. The team will discuss any safety hazards that were considered when creating the lawn mower. With safety, the team considered the environmental conditions that the lawn mower might have when in use. The team will use the Autonomous lawn mower for the benefit of society to use with safety measures that coincide with the IEEE. The results will be displayed and any consideration of the environment and manufacturability will be addressed. We will then conclude with the results to show that our Autonomous lawn mower will be active and ready to serve in the coming semester.

I. Executive Summary

Autonomous Lawn Mower	
Team Number: 16	Team Name: Autonomous Lawn Mower
Mentor: Gustavo Roig	Team Member: Blake Wolford
Team Leader: Jason Menendez	Team Member: Michael Szerman Ottaviano
Team Member: Mudassir Hussain	
Team Member: Fread Mohabir	

A. ***Summarized Problem Statement***

The Autonomous Lawn Mower is a robotic lawnmower cable for cutting grass without little to no need for human intervention. This device was built for the use of people who cannot mow their lawns due to their constraints. The team's vision for our autonomous lawn mower is to use sensory mechanisms to be able to cut grass for multiple houses. As the team develops the lawn mower to be as mechanically swift as possible, we noticed that the difference in houses might cause the need for an excessive amount of power. Due to this the team's focus is to construct an autonomous lawn mower that can cut grass and have a station for charging. The team's robotic lawnmower will be easy to use and will save money for our customers.

B. ***Objectives and Constraints***

The Autonomous Lawn Mower's Main objectives are listed, in addition to the constraints that should be acknowledged when constructing our autonomous Lawn Mower.

Objective:

1. The autonomous lawn mower must be user friendly
2. Must be safe to use
3. Cutting blades must be replaceable
4. User will be able to manually map out the lawn in the app

Constraints:

1. Battery life needs to last a minimum of 40 minutes
2. Must be able to navigate multiple lawns
3. The lawn mower should have an app that has no issues with distance connectivity

C. Project Description

The Autonomous lawn mower is a device that is cable of cutting grass as effectively as a regular lawnmower with the benefit of little to no interactions with the user. The Autonomous lawnmower will be able to cut the lawn with consistent results due to the sensors that will be available with the lawnmower. With the app that will be included with the automaton's lawn mower, it will be as simple as pressing a button to activate it. The Autonomous lawn mower makes cutting grass a thing of the past with its easy installation and effective capabilities.

*D. **Background***

When researching the different products that would be able to inspire our current design choices, we looked at top-selling products to understand what we need. They each share fundamental designs and are in likeness with our project. The first is the Worx Landroid S, we focused on this because of the interesting idea of creating multiple sizes depending on the yard instead of creating one size for all yards. Next, we have the Husqvarna Auto mower 435X AWD, this was the highest product as far as quality and versatility. The last the team saw was the Gardena 15108-41 Sileno Life, the company that created this technology has been gardening since 1961. All these companies have one thing in common and that is always making improvements to their product, this is the most important thing that our team was able to take away from researching our predecessors.

*E. **Budget***

An important aspect of our project was learning what the team can do with the current budget that was established. Our budget was looked over thoroughly by comparing it with the traditional lawnmower and what a robotic lawnmower would cost. The team then established what was necessary to equip ourselves with to build the bare minimum or what was required to construct the project. Using what was available to accomplish the construction of our prototype the team was able to go under our initial budget of $1000. The project was determined to be a total cost of $443.79 for our prototype to function as desired.

F. Intended users and Intended Uses

It is important to establish who this product is for; the team has concluded that the project will primarily be used by Lawn mowing professionals and Housekeepers. The uses are limited to lawn mowing and that is as far as the use of our technology will permit. The team's intention with this project is to be able to eliminate a remedial task that has long since been due a replacement.

In the age of new technology, the team aims to alleviate some minor chores that would otherwise be known as a hassle.

G. ***Conclusion***

The team's goal was always to create a project that would be accessible to the public and be able to assist in daily life. With the Autonomous lawn mower, we will create a device that will accomplish our goal and better the lives of the people. The team's previous projects which include circuit analysis, and programming applications will lead us to the proper execution of our project. Above all our project will have the objective of making life easier and more affordable for people to use every day.

II. PROBLEM STATEMENT

Any engineering project has a problem to be solved at its core. A concise and understandable issue description offers the project direction and guidance as a whole and assists to orient the collaborating engineers when periods of uncertainty or misunderstanding occur. A client's declaration of need serves as the main driving force behind the formulation of a formal issue description.

Lawns are typical in houses. Lawn maintenance is a chore similar to cleaning the dishes or sweeping the floor. Specific demographics find it challenging to take care of the lawn. The elderly may lack physical strength. Not everyone can afford a lawn maintenance service. Any householder would benefit from not having to worry about their lawns.

Lawn Robot is an autonomous robot that takes care of the lawn. The user can set the initial configuration using a mobile app connected to the robot. The robot is convenient to maintain. Once it is set up, the only task from the user is to clean the grass stored by the robot while cutting the lawn.

A. Objectives

1. Assembly
    - 1.1. Doghouse for charging station
    - 1.2. The robotic lawnmower must be durable
2. User friendly
    - 2.1. The cutting blades can be replaceable and easily obtainable.
    - 2.2. The robotic lawnmower must be user friendly.
3. Safety
    - 3.1. Must be safe to use around animals and children
4. Marketability
    - 4.1. Data from the system such as current or voltage will be measured for trouble cases.
    - 4.2. Data from the environment such as the number of objects encountered or the volume of grass cut will be measured locally and sent daily to a remote server.

B. Constraints

1. Battery life is to last a bare minimum of 40 minutes
2. Must be able to navigate different lawns
3. The robotic lawnmower should be inexpensive
4. The robotic lawnmower should have an app with no issues connecting from distances
5. The machine is waterproof
6. Sensory awareness of objects
7. A robotic lawnmower able to sense water and retreat to the safety

III. ASSUMPTIONS & LIMITATIONS

In this part, we'll go through some of the presumptions and constraints that will affect how our project is designed and put into action. These constraints were either purposefully set by the customer or project developers in the interest of making the project profitable, or they were required given the unique quirks of the medium we are working in. These limits can be divided into two broad, ill-defined categories that we call assumptions and limitations.

Assumptions, which are considered to be slightly less binding and more flexible, are limitations or requirements that were not imposed by the customer or by a definite physical limit. These will be the first contenders for areas that may be altered to ensure the effective completion of our project, should unanticipated problems arise during project execution.

Limitations are more stringent because they represent requirements put forward by the customer or by the tight physical bounds of a certain technology (or, in the most extreme example, the laws of nature). In other words, restrictions are those requirements that, if not satisfied, would result in the project failing since it would either be unable to be utilized or would not be helpful to the client, necessitating quick correction. These might include items such as the our project must have in order for it to operate inside another gadget of a certain size with, in which case it is evident how failing to fulfill that need would render the product unusable.

We discovered several features that would be useful for our product if incorporated through team research and many brainstorming sessions. Our team opted to include the most important features and leave specific ideas behind. The ideas not incorporated were due to a lack of time or budget. The timeline for the project is six months. Everyone on the team will work on the project 8 hours weekly at maximum because we are in college, so we have several other responsibilities. Our main goal is to develop a minimum viable product before spending more energy and money on the project. Some features left behind are solar panels for charging, batteries with the capacity to last a week, and navigation through complex terrains such as sand or rocks.

A. Assumptions

- The microprocessor has enough processing speed to run image or video recognition for the mapping.
- The blades are sharp enough to cut grass without affecting the internal gears of the robot.
- The Bluetooth connection between the robot and the user is reliable and won’t send erroneous information.
- Every one of our users has an Android phone to download the application.
- Wheels can travel through dry grass and wet grass without any problem.
- Long-time exposure under the sun won’t corrupt any inner circuit.
- The robot won’t have to avoid moving objects or animals like dogs.

B. Limitations

- The app is only for Android. Developing for iOS would require a Mac computer and a phone with iOS. Neither of the team programmers has them & acquiring them is out of our budget.
- The components must be cheap.
- The battery is charged with a wire.
- User must be nearby the robot to control it. The Bluetooth signal strength determines the range field.

IV. NEEDS FEASIBILITY ANALYSIS

Engineering projects that are offered by customers are frequently poorly organized and open-ended in the sense that they include requirements that are ambiguous or that can be achieved in a variety of ways. A requirements analysis is a methodical strategy to ascertain the true desires of a contracting customer and to accurately describe what they are looking for in a finished project. It includes several customer interviews, market and industry research, and is designed to paint a comprehensive picture of the project's nature from a variety of angles.

The feasibility analysis is a significant part of our project, this will be able to demonstrate the practicality of the project. In this portion, we have gathered the data from our team, our mentor, and or potential end users. The team was able to take their deliberation toward our feasibility and used this to further improve our design of the robotic lawnmower.

A. Needs Analysis

Our team will provide an outline of the feedback of the three listed members that contributed to the betterment of our device. Our needed analysis will provide the valuable information that will be the cornerstone that is the problem statement, our objectives for designing, and the restrictions to the information that we received from our mentor, team, and users. We started by asking our mentor about the real constraints that we would encounter when building our device. Our mentor was able to provide us with flaws and things that were feasible with our design team. After our mentor, we took a survey to gather the insight of the users, and asked questions such as “have you ever used a robotic lawnmower” or “what features are necessary to have with the robotic lawnmower.” The final part was a meeting of the design team to discuss feasible outcomes and a realistic view of what our product was to be.

1) Clients’ interview

Our interview began with our mentor, the team decided to first become acquainted with the reality of our project. The mentor that we chose was able to discuss with us the motive and the different possible uses for our robotic lawnmower. This was able to give us true insight into the inner mechanics that we would have to be facing during the time of construction. The outcome of that meeting is listed below in chart Table I.

TABLE I. RESPONSES RECEIVED FROM INTERVIEW WITH OUR CLIENT

Origin	Attribute
Meeting	Doghouse for a charging station
Meeting	The machine is waterproof
Meeting	Sensory awareness
Meeting	A camera that can rotate 180 degrees
Meeting	A robotic lawnmower is able to sense water and retreat inside if conditions are unfavorable for mowing lawns.

2) **User Survey**

The issue focused on Table II was the design team's friend's and family's perspectives on our robotic lawnmower. This would be able to give us insight into the current and past experiences with robotic lawnmowers. It would also be able to guide us in features that are to be expected from customers. As you can see Table II these are the responses that we received from our users.

TABLE II. RESPONSES RECEIVED FROM THE SURVEY

Origin	Responses
Survey	The robotic lawnmower should be inexpensive

Survey	The robotic lawnmower should be easy to operate
Survey	The robotic lawnmower should be able durable
Survey	The robotic lawnmower should have an app with no issues connecting from distances
Survey	The robotic lawnmower should have a battery life that at a bare minimum be able to cut the lawn in one cycle.
Survey	The robotic lawnmower should be safe to use around animals and children
Survey	The robotic lawnmower should have features outside of cutting grass

3) **Team Process**

After the survey and our mentor's suggestions, the team was provided with aspects that would aid in the development of the robotic lawnmower. We wanted to create a lawnmower with the ability to be able to navigate through different yards. This was important in the design team's thinking process because of the robotic lawnmowers' purpose, and convenience. With the ability to navigate we also concluded with its durability; the team wanted to make sure that the blades would be able to last, along with the machine itself. Our team made a chart of attributes that were needed for our design, the results are listed in Table III.

TABLE III. QUALITIES OBTAINED BY THE TEAM ANALYSIS

Origin	Quality
Team	Battery life is to last a bare minimum of 40 minutes
Team	The robotic lawnmower must be durable
Team	The cutting blades can be replaceable and easily obtainable
Team	Must be able to navigate different lawns
Team	The robotic lawnmower must be user friendly
Team	Data from the system such as current or voltage will be measured for trouble cases.
Team	Data from the environment such as the number of objects encountered or the volume of grass cut will be measured locally and sent daily to a remote server.

When our team collected the data required from the different outlets that we had we then collected all the information that we received and put up our results in Table IV to display them all. The team went over everything and any quality or suggestion that we found unnecessary or too enterprising was highlighted in Table IV.

TABLE IV. THE COLLECTION FROM USERS, TEAM, AND CLIENT

Origin	Responses and Qualities
Team	Battery life is to last a bare minimum of 40 minutes

Team	The robotic lawnmower must be durable
Team	The cutting blades can be replaceable and easily obtainable
Team	Must be able to navigate different lawns
Team	The robotic lawnmower must be user friendly
Team	Data from the environment such as the number of objects encountered or the volume of grass cut will be measured locally and sent daily to a remote server.
Team	Data from the system such as current or voltage will be measured for trouble cases.
Survey	The robotic lawnmower should be inexpensive
Survey	The robotic lawnmower should be easy to operate
Survey	The robotic lawnmower should be able durable
Survey	The robotic lawnmower should have an app with no issues connecting from distances
Survey	The robotic lawnmower should have a battery life that at a bare minimum be able to cut the lawn in one cycle.
Survey	The robotic lawnmower should be safe to use around animals and children
Survey	The robotic lawnmower should have features outside of cutting grass

Meetings	Doghouse for a charging station
Meetings	The machine is waterproof
Meetings	Sensory awareness for objects
Meetings	A camera that can rotate 180 degrees
Meetings	A robotic lawnmower able to sense water and retreat to the safety

The aftermath of omitting redundancy left us with the essential attributes needed for our project to thrive. After the team created Table V to demonstrate the objectives and constraints of the robotic lawnmower. Table V shows our team's objectives and constrains.

TABLE V. OBJECTIVES AND CONSTRAINTS

Origin	**Responses and Qualities**	**Variety**
Team	Battery life is to last a bare minimum of 40 minutes	Constraint
Team	The robotic lawnmower must be durable	Assembly
Team	The cutting blades can be replaceable and easily obtainable	User Friendly
Team	Must be able to navigate different lawns	Constraint

Team	Data from the system such as current or voltage will be measured for trouble cases.	Marketability
Team	Data from the environment such as the number of objects encountered or the volume of grass cut will be measured locally and sent daily to a remote server.	Marketability
Team	The robotic lawnmower must be user friendly	User Friendly
Survey	The robotic lawnmower should be inexpensive	Constraint
Survey	The robotic lawnmower should have an app with no issues connecting from distances	Constraint
Survey	The robotic lawnmower should be safe to use around animals and children	Safety
Meetings	Doghouse for a charging station	Assembly
Meetings	The machine is waterproof	Constraint

Meetings	Sensory awareness of objects	Constraint
Meetings	A robotic lawnmower able to sense water and retreat to the safety	Constraint

The final table, Table VI, displays the removal of all constraints and shows our team's objective for the project. With Table VI, we can see the necessary things for our project.

TABLE VI. OBJECTIVES

Origin	**Responses and Qualities**	**Variety**
Team	The robotic lawnmower must be durable	Assembly
Team	The cutting blades can be replaceable and easily obtainable	User Friendly
Team	The robotic lawnmower must be user friendly	User Friendly
Team	Data from the system such as current or voltage will	Marketability

	be measured for trouble cases.	
Team	Data from the environment such as the number of objects encountered or the volume of grass cut will be measured locally and sent daily to a remote server.	Marketability
Survey	The robotic lawnmower should be safe to use around animals and children	Safety
Meetings	Doghouse for a charging station	Assembly

The need analysis was able to give insight into the objectives that aligned with our ideas as well as our mentor and survey. Through this, the team was able to gather what was a need for us to be able to create our objectives. The data gathered shows that from our mentor's perspective it was inventing new ideas for the robotic lawnmower while the survey requested the robotic lawnmower be inexpensive and easy to use. From the charts, we can conclude that our product is to be used in a way that correlates to safety and ease of use.

1) **Problem statement**

Within the engineering world, our problem statement is a guide to lead us to the restrictions and goals that we can use when constructing our endeavors. These limitations that the problem statement can present are useful in the process when constructing our project. With our data collected, we can see our goals for the project and what hills we have to climb to achieve our vision. To begin, our robotic lawnmower's goal is to aid people with maintaining the lawn without any supervision required along with being able to do it with little to no maintenance required from the robotic lawnmower. The team's robotic lawnmower will be able to achieve most of these problems however there is a limitation to our goal. Specifically, regarding the issue of maintenance, the team has a blade that will be used that will eventually need replacing and most

of the time companies have to send parts later on or have someone come to install it for them. Our solution to this is to have a replaceable blade come with the robotic lawnmower and be able to replace them without the assistance of any professional.

2) **Objectives**

- Assembly
- Doghouse for charging station
- The robotic lawnmower must be durable
- User friendly
- The cutting blades can be replaceable and easily obtainable
- The robotic lawnmower must be user friendly
- Safety
- Must be safe to use around animals and children
- Marketability
- Data from the system such as current or voltage will be measured for trouble cases
- Data from the environment such as the number of objects encountered or the volume of grass cut will be measured locally and sent daily to a remote server.

3) **Constraints**

- Battery life is to last a bare minimum of 40 minutes
- Must be able to navigate different lawns
- The robotic lawnmower should be inexpensive
- The robotic lawnmower should have an app with no issues connecting from distances
- The machine is waterproof
- Sensory awareness of objects
- A robotic lawnmower able to sense water and retreat to the safety

B. Need Specification

In this section, the main goal is to define the quantitative and measurable aspects of the project. For this, we will attempt to transform the natural language aims and limitations stated in the previous section into concrete and easily measurable design characteristics.

After the clients' interview and understanding of their needs, the need specification assigns numerical values or metrics, so certain aspects of the projects are measurable. This part is essential because, without it, the objectives of this project would not be as clearly defined, and it would be hard to meet specific goals within the objectives without concrete parameters. The following Table VII will summarize the specifications and justifications of the metrics of the defined objectives.

Table VII. PERSPECTIVE ATTRIBUTES

Objective	Specification	Justification
D	Should have a controlling unit with these specifications: 1. At least a 32-bit processor with a 1GH clock speed 2. Bluetooth: max distance < 30m 3. WIFI: max distance < 50m 4. At least 20 mix signal GPIO	The robot would need a strong enough controlling unit with capabilities of machine learning and able to run programs quickly and store data. It would need good enough connectivity for wireless communications. Need at least 20 GPIO pins to attach various sensors.
A	Need material that's UV and water-resistant and able to withstand at most 120-degree heat.	The robot would need to have a durable enough body to protect the internals from water damage and keep the body stable in extreme heat.
C	Ultrasonic sensor with distance detection up to 50cm	Need sensors to detect objects, humans or animals in close proximity
B	Will be designed with a weight no more than 30 pounds and dimension under 22in x 15in x 10in	Lawn mower must be a decent weight and size so users are able to lift it

After the defining of the table, our team can build the product with parameters and metrics in mind. We have established quantitative values to certain objectives based on the discussion between the team and mentor. We defined the required processing power and connectives capabilities of the project. Metrics regarding durability were specified which is important for the longevity functions of the lawn mower. Another objective regarding safety and sensory detection was defined which is one of most important things to take into consideration when designing the

lawn mower. Finally the product dimension and weight were defined to satisfy certain user friendly goals.

C. Feasibility analysis

For our feasibility analysis, the team will analyze the different aspects of our project to determine whether certain parts of the project are worth spending time and money on. These aspects will be viewed in seven different ways and will be scored depending on the viewpoint of those aspects. From there the team will create a table to rank all scores to determine if the project is worth pursuing. The seven feasibility viewpoints we will be taking are technical feasibility, resource feasibility, economic feasibility, scheduling feasibility, legal feasibility, marketing feasibility, and cultural feasibility.

Each feasibility question will aid the team in determining the weight of each section. Questions from each section will have a response and depending on that response will be correlated with a score. This score can range from 1 to 5 and will be averaged at the end of each feasibility section. The team will then gather the data and create a weighted table to organize the scores to create the results of the feasibility analysis. The final score will be able to display if our project is achievable.

A. Technical Feasibility

The first section the team began with is the technical feasibility, this determines if the materials needed to construct the project are attainable. If it is not, will it require the creation of the such said piece? The team has researched and obtained items needed to construct a prototype for the current project and will continue to experiment for better results in the future. The results of the data came to be 3.5 as displayed in table VIII.

Table VIII Technical Feasibility analysis

Technical Feasibility			
Attribute	Score	Why?	Solution
Are we able to obtain the technology?	5	The team has researched all the necessary parts to aid us in our task.	The team reached this conclusion through research and actively acquiring the items needed. Most are in our possession.
Do we have the best material for the product?	3	Obtaining the best would require the team to go over budget.	The team will be able to achieve the task we have chosen with the best results for what we have.

Is there any technical risk?	3	There is no guarantee on the first attempt that we will succeed	The team's design of the robotic lawnmower has reflections on previous projects that the team has undertaken.
Will invention be needed for the project?	3	The invention charging unit will be needed to be invented from our own design	Have begun researching and brainstorming for possible designs.
Total	14		
Average	3.5		

B. Resource Feasibility

The next section will analyze the team's ability and tools needed to complete the project. This section displays the characteristics needed to complete the robotic lawnmower. The team's design when creating the robotic lawnmower was met with diligence and creativity. Our hard work and research will be able to directly reflect our final product. The team obtained an average of 4.25 from table IX.

Table IX Resource Feasibility Analysis

Resource Feasibility			
Attribute	Score	Why?	Solution
Do we have enough people?	5	The work has been evenly split between everyone with no issues.	No solution needed
Are there enough supplies to complete the project?	4	There are enough supplies but acquiring multiple may exceed our budget	We have already taken into account any problems we might encounter and adjusted for them.
Does the team have the programming and electronic skills needed to complete the project?	4	The team has never created a robotic lawnmower, and the team must invent an item for charging.	The team has worked on numerous projects in the past that will allow us to overcome most obstacles.
Is the team knowledgeable about the purpose of the project?	4	The team is limited due to the different majors we have	Where we are limited, we also can divide and conquer in the subjects that we know most
Total	17		
Average	4.25		

C. Economic Feasibility

This section deals with the economic feasibility, which will determine if the team is able to complete the project with the current budget that has been established. Table III will display information that will correlate if the project will be a burden to the team or if we are able to accomplish our goal without the drawback of finances. The average score was 3 as displayed in table X.

Table X Economic Feasibility Analysis

Economic Feasibility			
Attribute	Score	Why?	Solution
Is our budget restricting us from completing our project	3	Despite having parts already, the issue is obtaining extra parts in case of accidents or failure through trial.	We work carefully and diligently with what we have. Using 3D modeling when we can to avoid risks.
How much of an economic risk is there?	3	The team's ability to not waste products is to be determined in the coming weeks.	We approach with caution and if we need to the team will ask the mentor for guidance.
Total	6		
Average	3		

D. Schedule Feasibility

The Schedule Feasibility deals with the team's ability to meet deadlines and achieve milestones within the designated time frame. Another consideration would be our group's ability to recover from setbacks due to products not shipping out. The results of these questions are displayed in Table XI with an average score of 3.5.

Table XI Schedule Feasibility Analysis

Schedule Feasibility

Attribute	Score	Why?	Solution
Is there schedule risk?	3	Most of the members are separated from each other.	There are two that will be working on the physical design and the other three will work on the software.
Can we meet for the preliminary design review?	3	Team members will have difficulty ever being in the same location.	The solution to this is developing a better communication method and establishing dates in extreme advance so no complications will arise.
Will our milestones be met?	4	Our milestones will be met if parts are available to us.	We have already discussed actively purchasing as many parts as we can for each assignment.
Are we able to meet the critical design review?	4	The team is able to dedicate sufficient time to the project and its experiments.	Getting a better understanding on what is the critical design review.
Total	14		
Average	3.5		

E. Cultural Feasibility

The Cultural Feasibility reference to the team's project's effect on society when completed. This feasibility has already received a good reputation from previous competitors, with only complaints on request for more features. This answer was conjured from the results of the surveys that the team issued. This and the added benefit that a product like ours is on the market leads us to believe that the average score of table XII 4.5 is exactly what we anticipated.

Table XII Cultural Feasibility Analysis

Cultural Feasibility			
Attribute	Score	Why?	Solution
Is there any issue with use in a public area?	5	Our product is similar to those in the current market and is already in use.	No solution needed
Will the project have a positive social impact?	5	This will create an easier process for mowing lawns.	No solution needed

Are there any labor restrictions?	4	If this were to be successful it would take away the job of those who mow the lawn.	Our machine mows lawns but does not provide other services outside of just that. Therefore, it will only aid mowing services.
Is there any Cultural Risk to consider?	4	There is little to no risk due to our designs being similar to already approved products.	Perform unique developments with the safety of our future customers in mind.
Total	18		
Average	4.5		

F Legal Feasibility

The legal feasibility is required to discover if any laws will stop us from completing our project. After previously looking at our ethics section we can be sure that our design and our intention are in check with the code of ethics for engineers. In this section, the team reanalyzes for the legal feasibility to make sure that the team's project is not an issue. The team average score was 4 which can be shown in table XIII.

Table XIII Legal Feasibility analysis

Legal feasibility			
Attribute	Score	Why	Solution
How much legal risk is there?	3	The design is modeled by other existing products.	The team plans on attempting to make the robotic lawnmower its own product with its own unique features.
Is the law affected by our product?	5	No law is against the making of this product.	No solution needed
Does the Design conflict with the intellectual property?	4	To the team's knowledge, it should not have any conflict	The team will check with all available resources to make certain that there is no conflict.
Total	12		
Average	4		

G Marketing Feasibility

In order to see if our product is going to succeed the team will use the marketing feasibility table. With the data in the table, we will be able to see if our product is ready for the current market or if the time that we spend on it will be for nothing. This problem does not affect us because of the growing need for the 'good life' to be more present in the everyday life of people. Therefore, the average score that we received is 3.3 as to be shown in table XIV.

Table XIV Marketing Feasibility analysis

Marketing feasibility			
Attribute	Score	Why	Solution
Is there a marketing risk?	3	This is because of our product features that may or may not be similar to those on the market.	The team plans on making the product be set as an individual from the current products with a specific unique feature
Will the survey takers and public accept this product?	5	We have people already asking group members for a prototype.	No solution needed
Will it struggle against products like itself?	2	This is because of a lack of resources as well as no skills in marketing.	Wait till we have the best materials for the product and ensure the product is in the hands of someone who has experience in selling such products.
Total	10		
Average	3.3		

A. Ranking the Seven Feasibility analysis

The team will display the chosen method for demonstrating the importance of each of the feasibility. They will be determined by four different numbers equating to the importance of each. The numbers will be 1,3,5,7 each with different significance to importance. Table XV will be displayed which will compare all the elements in columns and rows.

A) Equally important=1
B) Moderately more important=3
C) Strongly more important=5
D) Most important=7

The geometrical mean will be calculated from Table XV

Within the geometrical mean, the ‘n’ is the total number of attributes, and the ‘x’ represents each attribute within the row.

$$G.M = \left(\prod_{i=1}^{n} x_i\right)^{\frac{1}{n}} = \sqrt[n]{x_1 x_2 \cdots x_n}$$

Weight=GM/Total

Table XV Operation for obtaining weights

	Technical	Resource	Economic	Schedule	Cultural	Legal	Marketing	G. Mean	Weight
Technical	1	1	5	3	1	7	5	2.45	0.142
Resource	1	1	5	3	3	3	7	2.66	0.154
Economic	3	3	1	1	1	3	3	1.87	0.108
Schedule	1	5	1	1	5	3	1	1.85	0.107
Cultural	1	5	1	3	1	3	1	1.72	0.100
Legal	3	5	5	5	5	1	5	3.69	0.214
Marketing	3	1	5	7	7	3	1	3.00	0.174
Total	17.24								

Now that the data has been collected, we are able to obtain the weighted score of each attribute and the average. The team will now proceed to the project feasibility assessment.

B) Project Feasibility Assessment:

The team will now be able to obtain the weight score with the given information from Table XVI. The weight score will be able to be obtained by using the attribute’s weight and then the score will be multiplied. The attributes will have the weighted scores and then divided by their weight only then will the team be able to have the weighted average.

Table XVI Weighted Score

	Weight	Score	W. Score
Technical	0.142	3.5	0.497
Resource	0.154	4.25	0.6545

Economic	0.108	3.0	0.324
Schedule	0.107	3.5	0.3745
Cultural	0.100	4.5	0.45
Legal	0.214	4.0	0.856
Marketing	0.174	3.3	0.5742
Total	0.999	26.05	3.73
Weighted Average			3.73

From Table XVI we have the final score of 3.73. This means that the overall score has proven that our project can succeed.

The goal of the feasibility was to prove that our project has the chance to be successful however it is not in stone. This is only encouragement for us to continue to work hard and keep thinking of new ideas to improve our design. The team's focus now is to begin prototype testing to ensure that the final product can be of us for the rest of the world.

D. Marketability

Marketability plays an essential role in the product appealing to the consumer within a targeted selling range while still profiting. No matter how skillfully crafted or beneficial the product is, it might now fall utterly and completely flat if it doesn't have a decent sustaining market. The standards for marketability will, in general, vary from product to product; yet, choosing how to present a product is a fundamental, basic, and often difficult decision. With an examination of various products and the capabilities behind them, it could provide the best possible usage expected to improve the overall objective arrangement for the promoting plan. To confirm that the project depicted has the correct statistic, a correlation of the advertising structure towards other comparable types of products can be made.

1. *Luba: Am Intelligent, Perimeter Wire Free Robot Lawn Mower*

Luba is rightfully owned by Mammotion and is part of AgileX. The start of the planning phase began in February 2021 and the product was launched on Kickstarter in May 2022.

a. Project Summary

Mammotion, the creator of the Luba Wire Free Robot Lawn Mower, was founded in January 2022. They aim to lead a more innovative, efficient, and eco-friendly outdoor lifestyle [1]. The company is now part of AgileX Robotics which was founded in 2016. AgileX Robotics has nearly

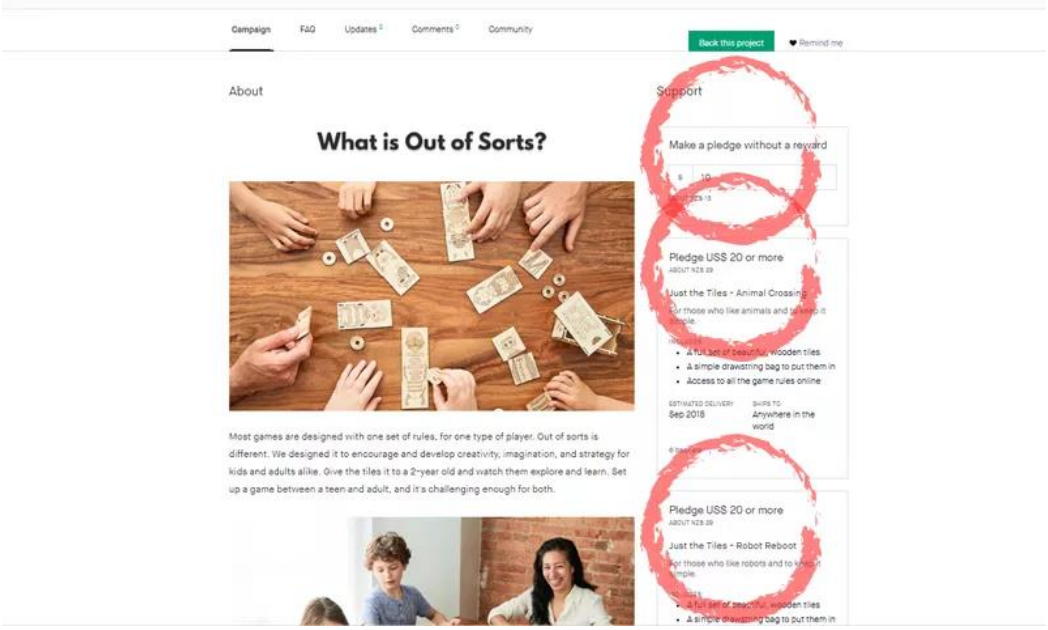
seven years of experience with algorithms and chassis-based hardware with robotics. Now that AgileX is part of Mammotion, they have leading designs for mobile robotic chassis, including the Luba Wire Free Robot Lawn Mower. Mammotion leads the UAV and robotics market, which includes a well-known company, Anker. This team made it possible to become a leader in the market with only 100 members, which leads to an efficient yet productive company. Mechanical control and sensor fusion are some of the robotic technologies the team has experience with. With more than 80 patents, the team was able to make this device a success [6].

b. Fundraising Strategies

1. Super Early Bird 52% off includes:
2. Mammotion Luba with installed blades at $1,199
3. Mammotion App Access
4. 8 Piece set of extra blades
5. Early Bird Special 48% off includes:
6. Mammotion Luba with installed blades at $1,299
7. Mammotion App Access
8. 8 Piece set of extra blades
9. Kickstarter Special 40% off includes:
10. Mammotion Luba with installed blades at $1,499
11. Mammotion App Access
12. Mammotion Drawstring Backpack
13. 2 x 8 Piece set of extra blades
14. Early Bird Bundle Special 48% off includes:
15. 2 Mammotion Luba's with installed blades at $2,598
16. Mammotion App Access
17. 2 x 8 Piece set of extra blades
18. Early Bird 48% off includes:
19. Mammotion Luba with installed blades at $1,299
20. Mammotion App Access
21. Mammotion Drawstring Backpack
22. 8 Piece set of extra blades
23. Super Early Bird Bundle 52% off includes:
24. 2 Mammotion Luba's with installed blades at $2,398
25. Mammotion App Access
26. 8 Piece set of extra blades
27. Early Bird Bundle 48% off includes
28. 2 Mammotion Luba's with installed blades at $2,400
29. Mammotion App Access
30. 8 Piece set of extra blades

The way Mammotion was able to get funding using Kickstarter was by having backers pledge with an incentive with discounted items and other free incentives like a backpack and free replacement blades. When a backer pledges for a fee, they will receive the device at the listed

price. They will also receive gifted items if it is included with the pledge the backer signed up for on a specified date included in the description of the pledge. With this way of fundraising, Mammotion gained 2,444 backers with total funding of $26,505,634 [6].



The early birds deal proposed before would go in the highlighted red circles.

c. Technology Overview

Luba uses Wi-Fi connectivity, Bluetooth technology, and cellular connectivity with a paid subscription. These ways of connectivity allow the device to stay connected for control with the smartphone application. The device has a 10Ah lithium-ion battery with a charge time of 150 minutes [1]. The sensors on the device are an RTK antenna used for real time kinematics, lift and tilt sensors, ultrasonic sensors for object detection and GPS for tracking and theft prevention, and a bump sensor for when the device's ultrasonic sensors fail to detect an obstruction in its path. The standard height of the RTK antenna receiver is 1.8m. You can also set the antenna on the roof of your house. Please note that additional extension rods or installation kits are included in the Luba package. The device has 4-76 Watt motors as well. The adapter can be connected directly to a 110-240V power supply. Table VIII describes the technical specifications.

TABLE XVII. LUBA SPECIFICATIONS

Part	Technology	Functionality
Power	10Ah Lithium-Ion Battery	The power supply for the unit to function.

Sensors	RTK Antenna Lift Sensors Tilt Sensors Ultrasonic Sensors GPS Bump Sensor	The various sensors are used for real-time kinematics to set boundaries, if the device is lifted off the ground, if the unit is tilted and obstacle detection, for theft prevention tracking, and for when the ultrasonic sensors fail to detect an obstruction.
Wireless	Bluetooth Wi-Fi Cellular	Bluetooth, Wi-Fi and cellular is used for app communication to control the device and its features.
Smartphone App	iPhone IOS 11+ Android 4.1+	The app allows connectivity to the device. It sets boundaries and object detection. Allows you to start, stop and dock the device to its charger. It also lets you start a schedule on when to start mowing.
Motors	4-76 Watt motors	The motors help with the propulsion of the device and spinning of the blades

Equipped with hub Motor and Four Rugged Tires, Luba has an intensive power output and easily passes through different mowing zones. Luba won't get stuck at any uneven and rugged spots and can handle up to 75% slope (about 38°).

d) System Description

Luba connects directly to services in ways of Bluetooth, Wi-Fi and cellular connection. This allows for the device to communicate and for the user to be able to use the app shown in Fig. 1.

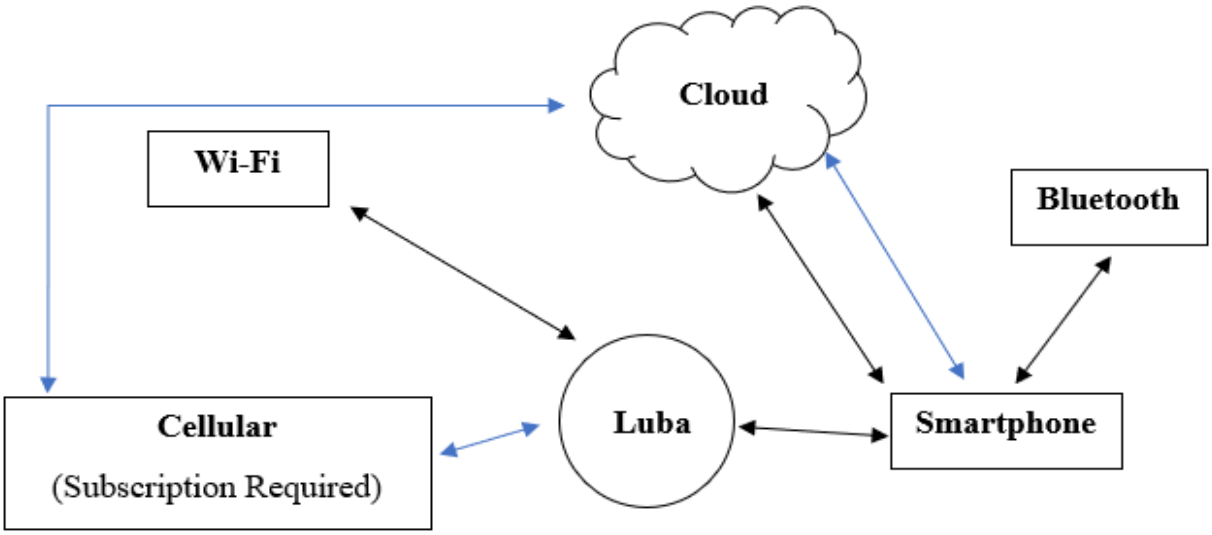


Fig. 1 shows all ways of communication for control in the smartphone application. The blue arrows show how cellular connection is communicated.

The app also allows real time tracking of the mower's status communicating in the ways discussed shown in Fig. 2 [6].

Fig. 2. Luba communicating using RTK and cellular connection for the smartphone application [6].

A 10Ah lithium-ion battery provides enough power to roughly cover 1500 m^2 per charge. The

unit has 4-76 Watt motors for moving the mower, cutting and being able to ascend a max slope of 75% [7]. The battery provides an ample amount of power to operate these motors. The charger for this device will charge the battery within 150 minutes and will auto recharge utilizing the real-time kinematics map and GPS to locate the dock to start charging. With the battery capacity and the amount of power the motors used combined, it can lead to cutting 5000 m^2 on average. It is IPX6 waterproof so the device can get wet from rain or cleaning under high pressure although if flooding occurs, it may not be protected with an IPX6 rating. To detect rain LUBA come equip with a rain sensor. The Rain Sensor enables Luba to detect rain , and it will automatically go back to the charging dock to prevent catching the rain. When the rain stops, LUBA will continue the unfinished mowing task. In addition, Luba has an IPX6 waterproof level, but we advise not to mow on rainy days for a healthier lawn.

Kickstart might be an option to considerate to raise the budget we need for our project. Based on what we previously observe in the kickstarter campaigns there certain steps that we should follow to have a successful fundraising:

Define a clear objective: The amount required to build the product must be assessed. In this situation, a realistic objective must be set in order to cover the product's financial needs. If the objective is not met, no money is paid; nevertheless, if the product is incorrectly financed, there may not be enough money to produce it. We have chosen to set a goal of $ 1000 after carefully assessing our project and its anticipated components.

Define the rewards: Setting prizes that are not just intriguing but also reasonably priced is crucial because Kickstarter's reward system works well to entice backers to give money. Since we are seeking funding to complete our prototype rather than launch production. We would give the following benefits:

- $ 15. Written letter saying thank you.
- $ 200. Discount for early adopters. + Previous Rewards.
- $ 500. A private 1-hour Zoom session with the entire team. + Previous rewards.

Create a video: Every successful campaign has a demo or presentation brief video of the product.

Use laymen terms: Everyone should be able to understand what the product is about, why we build it and how. Not everyone is an engineer or a technical background. Therefore, using simple terms to describe the product is important to reach a broad category of consumers.

In summary, a product's marketability determines if it will appeal to consumers and sell at a given price range to make a profit. Every business needs a waste management system to help

preserve a clean environment for everyone.

V. RISK ANALYSIS

When considering projects, it is an engineer's job to consider the many possibilities that revolve around that project. There are times when the product's intended use can be misinterpreted or used for ill intent. It is the job of the engineer to prevent this by using risk management to ensure the safety of those that come into contact with the device that they created. To ensure the safety of those using our product and determine the type of risks the seven categories of risk will be analyzed. In order, it will be Schedule, cultural, legal, marketing, economic, resource, and final technical.

The team's goal for this section will use the data that the team has collected to view the potential risks of our robotic lawnmower. This will lead the team into using specific materials or a different process when constructing to ensure that no harm comes to those that use our device. The tools that we will be using will consist of a fault tree, a Actions to Minimize risk table, and risk exposure. The team will display the risks within the seven categories that were previously mentioned.

1) Schedule

   S1. The team's ability to communicate at the same time

   S2. Inability to have all team members at the same location at the same time

2) Cultural

   C1. Ability to acquire older members of society to accept new technology

3) Legal

   L1. Patents on a specific process or parts used for the creation of robotic lawnmowers

   L2. Product liability

4) Marketing

   M1. Competition within the industry of similar product

   M2. Being able to rise above similar products through unique design choices

5) Economic

   E1. Exceeding budget

   E2. Not financially able to acquire the best materials

6) Resource

   R1. Having acceptable working conditions for construction

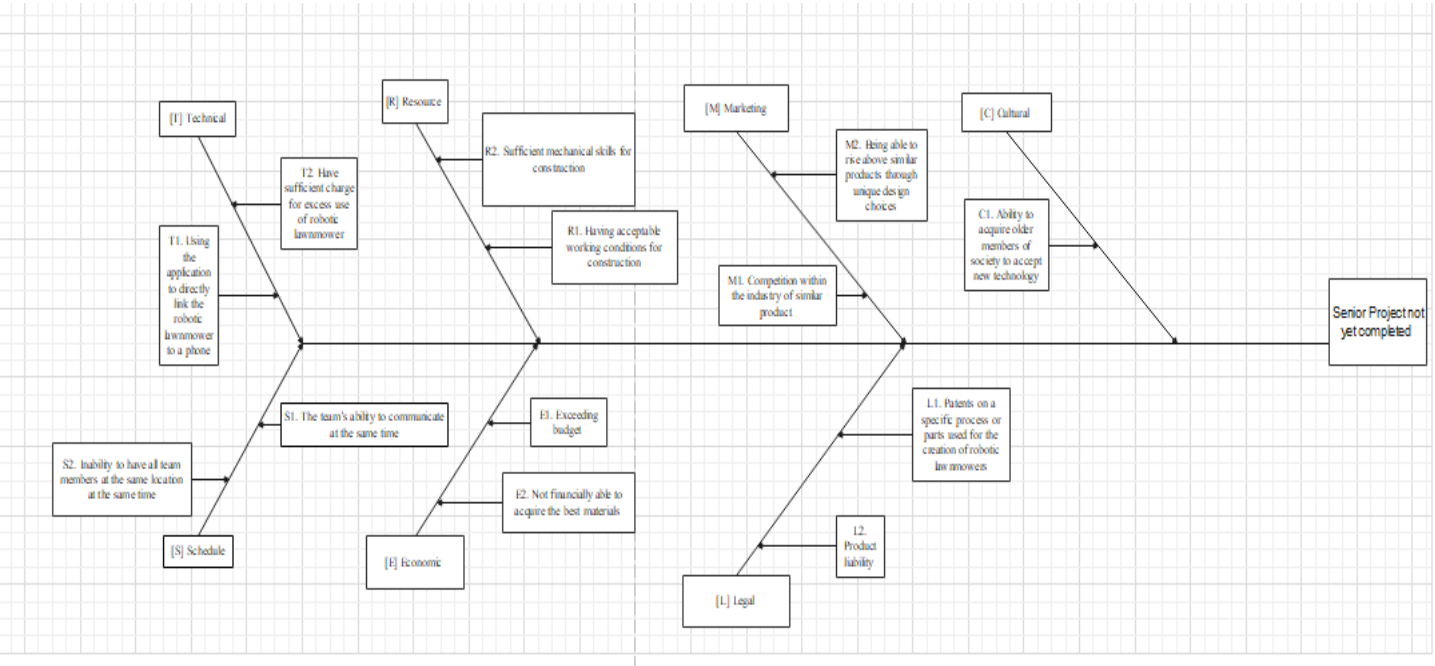
   R2. Sufficient mechanical skills for construction

7) Technical

T1. Using the application to directly link the robotic lawnmower to a phone

T2. Have sufficient charge for excess use of a robotic lawnmower

Fault Tree Analysis



The Fault Tree Analysis in Figure XVIII was used to display risks with the robotic lawnmower so that the team is allowed to assess the risk and treat them accordingly. The larger boxes that were created were the general categories and the smaller boxes were problems with those categories. This was created in this format to allow the team to be as organized as possible for quicker and more concise solutions. To begin with the Technical boxes, the problem was having the robotic lawnmower charge enough for our devices to function for the task and being able to achieve a proper connection with the app interface. Next, we have Scheduling which is an issue for us because of the lack of communication due to different circumstances and the team's lack ability to gather in the same location. The team moved on resources, the team's ability to obtain the materials is something that was contemplated for a time but more so was the environment and the skills needed to specifically design our project with our lack of mechanical skills. The Economic branch was what keeps the team grounded in our vision, this is because of the issue of exceeding our

budget and not being able to purchase the best materials. This leads us to the marketing branch which leads our team into problems such as competition within the industry of similar products and being able to make our device unique enough so that our product is distinguished from those like itself. When the team was creating designs to make the robotic lawnmower similar and different from previous designs we ran into the Legal side of the product liability and the particular patents that may hinder us from using when creating our designs. This brings us to the final branch which was the Cultural branch, this branch is the end game for our project, the idea of society accepting our project and not seeing it as a gag in particular to those of an older generation. Table XIX displays Risk Exposure Matrix.

Table XIX Risk Exposure Matrix

Likelihood Of Occurrence	Very Likely	Possible	Unlikely	Legend
Class IV		[T2]	[L2][T1]	Catastrophic
Class III	[S2][M1]	[L1][E2][R2]	[R1]	Severe
Class II	[M2]	[S1][E1]		Moderate
Class I			[C1]	Low

Table XIX demonstrates the level of risk each problem has. By classifying each with the Risk Exposure Matrix the team can identify which risk should be a significant problem and which is less of a problem. The structure of this table is classified into four sections, very likely possible, and unlikely, the team was able to place problems that we felt were according. On the rightmost column was the level of threat to our project, the team was able to reassess potential and most immediate problems with this chart to properly proceed forward with design intentions. Each row and column was designed to the team's benefit for identifying which risk was immediate and which risk was not as threatening, and now that the team knows we can proceed forward with fewer doubts in our minds.

Actions To Mitigate Risk Table XX

Risk	Action
[C1]	Discuss with the mentor to guide us on the social acceptance of our robotic lawnmower.
[S1]	Being able to create a time schedule to better aid communication between all members.

[E1]	Discuss with the team to ensure proper use of materials and use the guidance of our mentor.
[R1]	Take steps to reserve or rent places where our working conditions are able to provide the members of the group with safety and resources.
[M2]	Learn more about the uniqueness of our project and focus less on making a product that is sellable on the market.
[L1]	Discuss with the team's mentor on the products that have similar design components.
[E2]	Using our mentor's previous experience to be able to determine the most important parts so the team can spend our budget on parts that will be able to ensure our vision.
[R2]	Taking our time with the limited resources we have and using 3Dmodels to test our designs before any actual work.
[S2]	Zooming calling while working on the project has bred positive results for previous assignments including all previous assignments for this project.
[M1]	Use all resources and mentor to analyze competition's marketing tactics.
[L2]	Have an additional survey sent out for understanding contracts as well as meeting with our mentor.
[T1]	Members have had previous app experience and are able to connect the app with the robotic lawnmower.
[T2]	Use appropriate voltage and battery amount when constructing the robotic lawnmower.

The final process of risk management is to list all actions to be taken while knowing all possible risks to our project. This approach either directly solves the problem or solves the symptoms of the problem. The team was listed from less threatening to most treating, the top being the least threatening and the bottom being the most threatening. The colors that are displayed are there to resemble the risk exposure matrix for a better understanding of potential risk. This can be all found within Table XX. All risks that have been discussed within this report and the team will be addressed and handled for the betterment of the project and the safety of those around our robotic lawnmower.

In conclusion, the team has been aware of potential problems since the beginning of the project and has begun solving these problems. This process of physically writing down and creating the tables can focus our attention on these problems. Our goal is to be able to bring comfortability with our product and have a project that we can all say helped our society.

VI. Operating Environment

The environmental impact of any project must be taken into serious consideration. This section describes the measures the team took to guarantee that the product's development and manufacturing did not have a negative impact on the environment. The engineer's responsibility is to make wise decisions regarding the materials utilized, the waste produced, and the product's sustainability. Furthermore, it is necessary to comprehend and stop any adverse effects on consumer and producer health by abiding by significant guidelines established by international organizations that attempt to conserve the environment.

There are chemical components that present a significant health risk if misused. Lead & Mercury can cause cancer or other serious diseases when consumed. The EU has a directive called Restriction of Hazardous Substances (RoHS) to prevent this. In the US, no federal laws are forcing this. Only 8 U.S. states force electronic devices to compel the RoHS. [1] Since our team cares about our users will follow the RoHS guideline by not having more substance concentration than the recommended:

- Lead < 0.1% by weight
- Mercury < 0.1% by weight
- Hexavalent Chromium < 0.1% by weight
- Cadmium < 0.01% by weight
- Polybrominated biphenyls (PBB) < 0.1% by weight
- Polybrominated diphenyl ethers (PBDE) < 0.1% by weight
- Bis(2-Ethylhexyl) phthalate (DEHP) < 0.1% by weight
- Benzyl butyl phthalate (BBP) < 0.1% by weight
- Dibutyl phthalate (DBP) < 0.1% by weight
- Diisobutyl phthalate (DIBP) < 0.1% by weight

The design of the Lawn Robot let the user to easily change individual parts that make up the product. The importance of replaceability is to recycle the working parts. Decreasing the quantity of material going to the trash increase environmental sustainability. The extraction of the materials used in the production of each part of the robot emits CO_2.[2] The product's design will avoid soldering or irreversible operations on the circuit to achieve this. The app will be easily linkable to a new Bluetooth device in case it is replaced.

The lawn's environment must comply with certain conditions for the robot to fulfill its duty. There can’t be tall or hard objects on the lawn. The robot won’t be able to move them. It could dodge them. It won’t cut under the grass beneath those objects. The wind can’t be intense enough to blow away the robot. The robot shouldn’t be used or remain outdoors in turbulent weather such as when a hurricane occurs.

The robot will absorb the grass cut. It is important to conserve a clean lawn by assimilating how a professional lawn mowing service would do it. This includes the grass well cut, and no waste remains. This can be achieved with small high intensive air blowers to pull leftovers and store them inside the robot container.

VII. Intended User(s) and Use(s)

The project design and objectives are heavily influenced by the intended users and usage. Thereby, listing them can help us not lose focus on what matters during the project's development.

Many features can be implemented. Due to the constraints and limitations discussed before, we prioritize doing the most important based on the users and uses. Our product should be a replacement for professional lawn mowing services. However, some of them may use them in their service for convenience.

A. Intended User(s)

User(s) are people who have the problems described in the former sections of the proposals, and our product can help. The intended user(s) for the lawn robot are the following:

- Housekeepers
- House owners
- Lawn Mowing Professionals
- Gardeners

B. Intended Use(s)

The intended use(s) for the lawn robot are the following:

- Lawn Mowing
- Absorption of grass and leaves on the lawn.

VIII. Background

In the modern world where technology advances as quickly as it does, it is best to build upon the progress already made in a given area in the design phase of a new product. Household robots have been on the market for some time, including many great automated lawnmowers, and this background has informed our design of this project by giving a head-start in identifying some of the areas where existing mowers need improvement as well as the fundamental design features that make them work.

All current robotic mowers share a great deal in common when it comes to the high level technological theory. Boundary wire is connected from a central hub and extended out to define the limits of the property within which the device is meant to mow. With current running through these wires, ultrasonic sensors in the mower sense these boundary markers when they are approached and the mower is steered in a new direction such that it will cover the whole yard in random motions. When the battery begins to run low, the mower will navigate back to a charging dock until it is ready to start again.

Within this design, there is a lot of flexibility, and various manufacturers have created mowers with differing characteristics to target certain specific applications. Some mowers have companion smartphone apps or other software to control and automate the device while others have a remote control. There are also many different interfaces on the robot itself including various kinds of displays, knobs, and buttons. Chassis design varies as well depending on how extreme the target operating conditions are be they weather, terrain incline, etc.. Robots designed specifically for small lawns in the city often direct their design and marketing focus on soundproofing to reduce noise and not disturb neighbors. Perhaps the biggest distinguishing feature is the size of the battery as this is the limiting factor on how large a lawn can be maintained with a given mower.

We found three different robotic lawnmowers on the market currently that highlight many of these differences. They all share the aforementioned fundamental design and will have that in common with the project we are proposing here, but the auxiliary features differ and shed light on some of the possible weaknesses of what is currently on offer to consumers. All the listed mowers below feature three cutting blades on floating discs that allow the height to be adjusted as the mower goes over uneven terrain, a charging base connected to a house outlet as a power source, and Bluetooth and/or WiFi-connected apps to control the mower.

A. Worx Landroid S

Worx is a tool company producing drills, blowers, workstations, mowers, and other related equipment. Their Landroid M is the highest ranked robotic lawnmower of 2022 in [14]. We looked rather at the Landroid S which is the smallest model to become familiar with the kinds of products at the entry level of the automated mower market.

1) Summary:

Fig. 3. Worx Landroid S [15]

The Worx Landroid S is one of the three available Landroid robotic lawnmower models named "S", "M", and "L". As the name might suggest, the Landroid S is the smallest and cheapest model in the product lineup built primarily for small yards under 1/8 of an acre in size. It is powered by a 2.0Ah battery that is recharged at the provided base. This charging base has an optional cover accessory making it into a sort of garage to help shelter the mower from overheating as well as from the elements. One of the Landroid's unique features is the availability of modular add-on devices that allow users to select and purchase only the specific features they want without needing to pay for functionality that would be unnecessary for them. These additional modules include:

- Anti-collision sensors
- Digital fencing devices (to more easily block off "No-Go" locations in the yard)
- An anti-theft module that uses cellular data to lock the mower if it is taken off the property
- A WiFi extender to maintain better connection in larger or more spread out yards
- Voice control and alarm module [16]

While these add-on features give the Landroid a somewhat unique space in the robotic lawnmower market, they do not make a particularly large difference in the starting price to the customer. A base model Landroid S retails at $999.99 without any of these additional devices, and the price increases in the M and L models as the battery size increases [15].

2) Technology Overview:

Although the Landroid S is the smallest of the lineup, there is a lot of technology fit in the 20x14.2x8.1 inch body [17].

- Microprocessor
- Ultrasonic sensors
- Rain sensor
- LCD display
- USB port for firmware updates
- Microphone (voice control module)
- Safety blade shutoff button
- 2.0Ah lithium-ion battery
- 3 angling mower blades
- 3 wheels (4 wheels on the M and L models)
- WiFi/Bluetooth transceiver
- Blade height dial
- Wheel motors
- Blade angling motors

3) System Description:

As shown in Fig. 4., the boundary wires, charging dock, and user input are all external to the mower itself and all constitute input that must be processed and handled by it. The user may use either the interface on the mower itself which consists of the shutoff button and mowing height knob, or he/she may use the mobile application on their smartphone to control the device. This data is sent to the mower for processing which will then mow at the height and on the schedule set by the user. The charging dock recharges the battery when the mower returns to it. The boundary wires are powered by that battery and are detected by the ultrasonic sensors to prevent the mower from escaping the property it is meant to maintain.

One of the Landroid's key features is its modularity, hence there are numerous modules denoted as optional to indicate that they may not be present in a basic Landroid setup. All these feed from built-in hardware such as the ultrasonic sensors, rain sensors, and the microphone, and interface with the central processing center which is the microprocessor. From there, relevant data is fed to the output display and back to the app for the user's review. The microprocessor also controls the wheels and blades to move the device forward and to prevent the blades from damage or cutting unevenly.

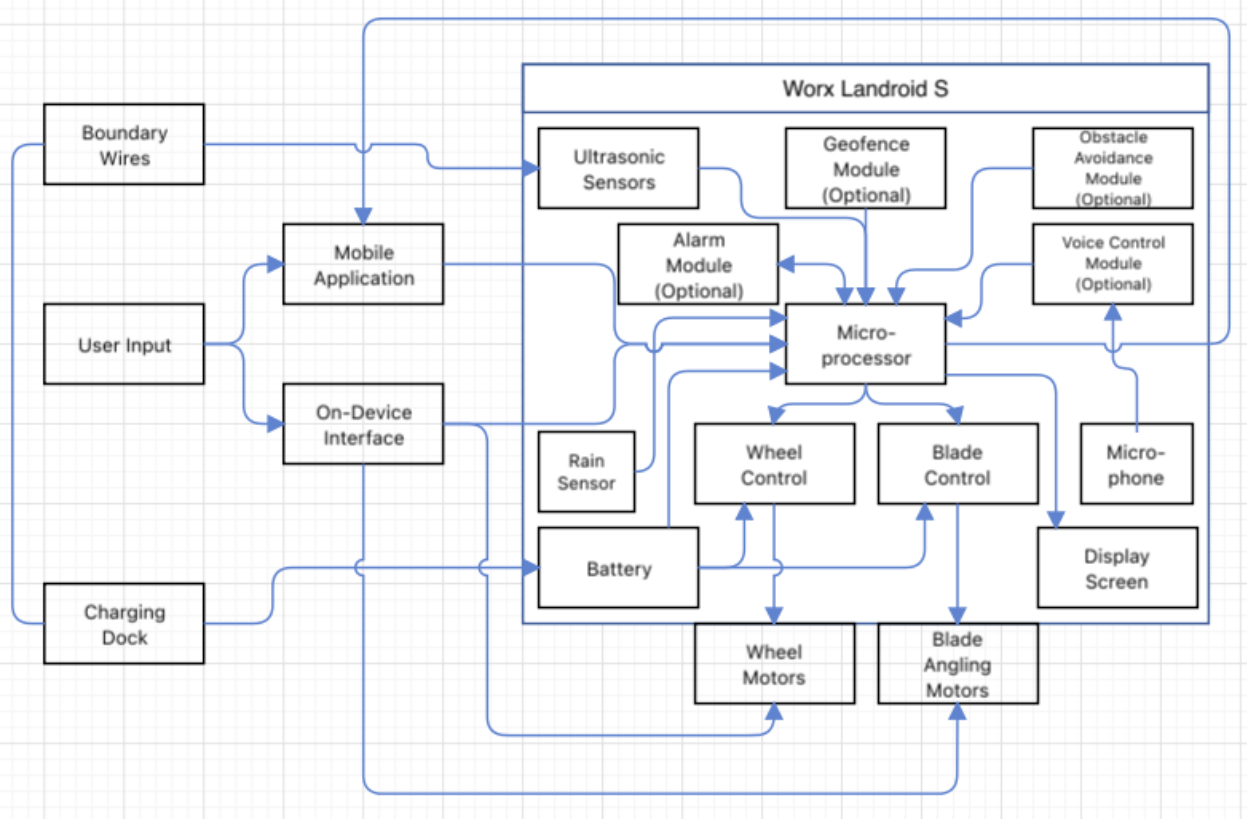


Fig. 4. Block diagram of the Worx Landroid S

The Landroid S is a flexible robotic mowing solution provided the target lawn for it to mow is small enough or that the user is interested in upgrading to a larger and even more expensive version to accommodate a larger property. It is not particularly quiet compared to other devices in its class clocking in at up to 67 dB [17]. However, for small yards with a maximum incline of 20º (35% grade) [15], the Landroid can accommodate many basic needs. Our project would ideally emulate and build on the rain sensing feature to prevent messy yard clippings or water damage to the device as well as creative tweaks to the charging dock to make it more hospitable for the device during inclement conditions.

B. Husqvarna Automower® 435X AWD

Having looked at a relatively entry-level product, we turned our attention to one touting some of the highest quality, versatility, and price on the consumer market. Husqvarna is well known for their lawn care devices including autonomous mowers similar to that of this project, and the Automower® X series are some of their most prestigious offerings in that category currently. The 435X is near but not quite at the top of the price list for these machines from Husqvarna, so it seemed worthwhile to consult one of the more advanced mowers on the market to see what the cutting edge of this technology can do.

Fig. 5. Block diagram of the Worx Landroid S

1) Summary:

The Automower® 435X's focus is on versatility and durability while bringing an extensive feature set to bear as well. It features a four-wheel, all wheel drive design with two distinct body sections that allow the device to pivot precisely and accommodate much steeper hills than other mowers in its class (35º or 70% grade according to [18]). The ability to mow versatile terrains such as this is the Automower® 435X's main selling point, and it does it while operating very quietly. It comes with a plethora of physical sensors which, when combined with the built-in GPS sensor, allow it to make a virtual map of the lawn [20]. The user can create zones in this virtual map where the mower is not allowed to go which allows an ease of control not achievable in cheaper devices of this sort. In addition to the well-featured application, the mower itself has a full-color display, jog wheel, and status-indicating lights to communicate information and allow for user control.

All these features come at a cost, however, and that is where the Automower® 435X struggles the most. The machine retails for $4,799.99 at time of writing which is enough to price many customers out of the market. That challenge is made somewhat worse by the still limited battery capacity making the Automower® fit for yards of only approximately 0.9 acres. That price may still be worthwhile to some customers, however, if they have a yard that size with difficult terrain that cannot be cut by other autonomous mowers but still want to pass that chore off to a robot rather than do it themselves. And for those nervous about theft having made such a large investment, they can rest assured that the Automower® 435X comes with built-in GPS that will prevent theft by way of a geofence around the property.

2) Technology Overview:

Similar to all projects of this sort, there are many sensors and other parts formed together to make a complex robot. Within the 36.6x21.7x11.4 inch device from Husqvarna there are:

- Microprocessor
- Ultrasonic sensors (and others not disclosed)
- On-device UI (user interface)
- Color display

- Jog wheel
- Stop button
- Start button
- LED indicator
- Charging LED
- Headlights
- 5.0Ah lithium-ion battery
- 3 angling mower blades
- 4 wheels
- All wheel drive — front and rear motors
- WiFi/Bluetooth transceiver
- Blade angling motors

3) System Description:

Per Fig. 6., the boundary wires, charging dock, and user input are once again depicted as external inputs. The user may interact with the mower via the jog wheel on the mower's physical UI or through the app virtually. Data from this is processed by the microprocessor in the mower, only for this device the sensor set is more extensive than those in section VIII.A as the Automower® 435X has additional modules built in. Sensors on the front of the mower inform the Obstacle Avoidance Module of impending collisions. The microprocessor will communicate an appropriate course of action to the wheels and blades to avoid collisions. The Balance Control Module senses when the mower is in danger of flipping and adjusts to prevent it from happening. The Geofence module connects to the GPS to alert the microprocessor in the event of theft. The microprocessor also outputs relevant data to the display and application for the user to be informed. The charging dock recharges the mower battery and powers the boundary wires. The boundary wires are, as in other designs, detected by the ultrasonic sensors to prevent the mower from getting lost.

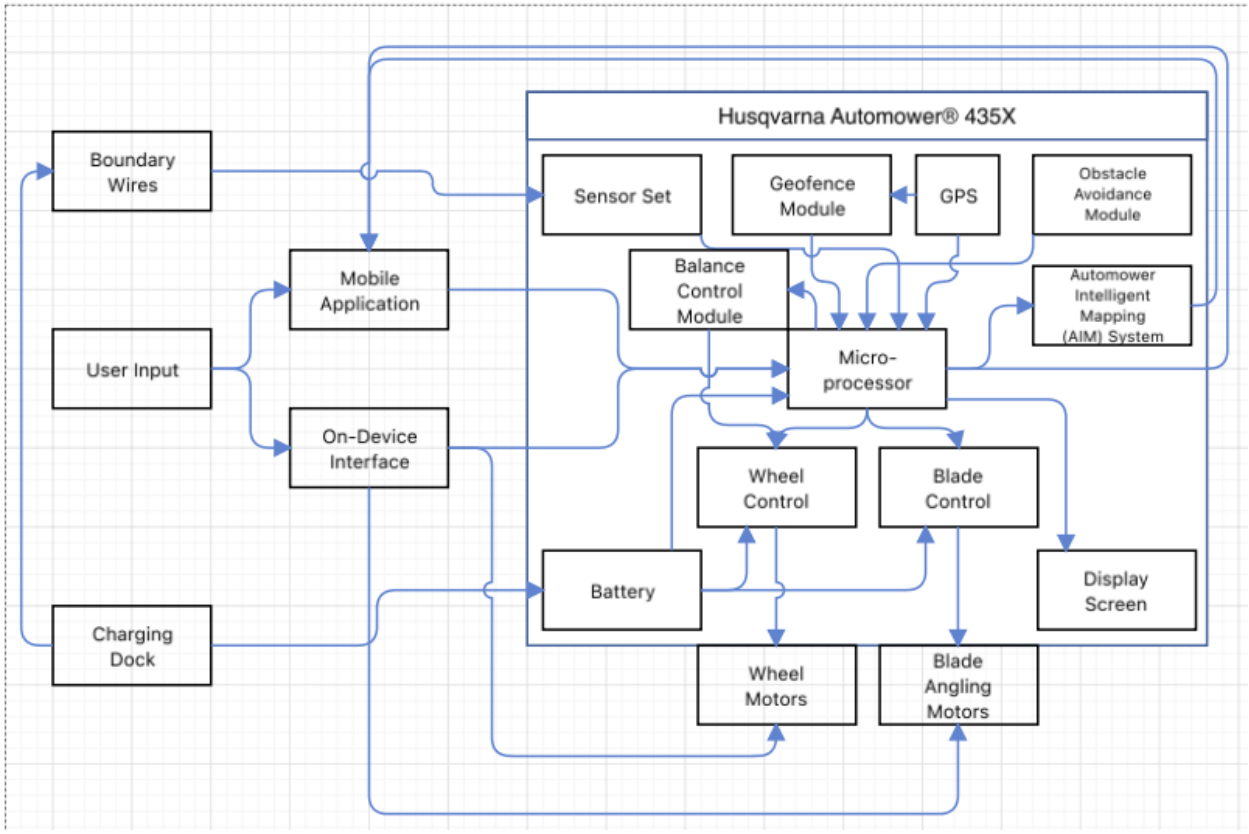


Fig. 6. Block diagram of the Husqvarna Automower® 435X AWD

While it is quite expensive, the Automower® 435X fills a niche in the autonomous mowing market by providing best-in-class reliability when it comes to mowing lawns of steep or extreme terrain. It comes with a host of features and a cleverly developed body design that allows it to execute its function in this niche effectively and enables Husqvarna to profit from it as they do. Even with its rugged competence, it retains an excellent sound rating of 60 dB [19]. With the biggest hurdle for the Automower® 435X to overcome being the price, the question should be asked: what parts can be optimized or eliminated to reduce the price without diminishing the experience? While the User Manual claims the GPS Assisted Navigation helps the product "select the most optimal operation" [19, Sec. 3.4.6], it also states that the cutting pattern is random [19, Sec. 1.2], so the available documentation is very vague about that for which the GPS is used. In our project, we would like to eliminate this kind of bloating and focus on implementing only the most useful and necessary components to accomplish our user's tasks.

C. Gardena 15108-41 SILENO Life

Gardena is a gardening company established in 1961 by Werner Kress and Eberhard Kastner and was acquired as a member division of Husqvarna in 2007 [21]. Since that time, Gardena has been primarily focused on smart gardening equipment from sprinklers to—since 2012—autonomous lawnmowers.

1) Summary:

Fig. 7. Gardena SILENO Life [22]

The SILENO Life is the flagship robot from Gardena that features a stylish and functional chassis with best-in-class sound reduction coming in at just 57 dB. As its name might indicate, the SILENO is marketed as a mower that will not wake up the neighbors and all the while will keep the lawn consistently cut and healthy with little to no human effort. The chassis also features excellent waterproofing that allows it to cut even while it is raining. In addition, cleaning the SILENO Life is made very simple as it can simply be hosed off with a garden hose. Like other machines in its class, boundary wire is placed around the perimeter of the property to corral the mower in while it moves around randomly inside to cover the whole surface of the yard. The SILENO Life's small frame allows it to fit through narrow corridors easily. As is the case with the other devices in sections VIII.A and VIII.B, Gardena has a mobile app that allows the SILENO to be controlled remotely as well. Conversely, the on-device interface is kept to an absolute minimum with an emergency shutoff button and a monochrome display.

The SILENO Life is more focused on thoughtful improvements to existing designs than radical excess in sensors and features. The chassis is sturdy, and the sensors that are used are used intelligently. One example is the use of a thermal sensor to detect when the weather is cold enough that cutting the grass would result in poorer health for the lawn at which point the robot would stay on its charger and wait for a better time to mow. The app also features a spot cutting feature that

prompts the device to mow outward in a circle rather than randomly to address some areas that are more difficult to access.

While the SILENO Life is among Gardena's flagship designs, in the broader market, it situates itself in a happy middle space between cheaper, less refined mowers and excessive products that are out of reach for most consumers in terms of price. It costs $1,399.99 and will mow a lawn of around 0.38 acres quietly. While it is not intended for use on steep hills, this product handles itself well at the industry-standard slope of 20º (35% grade) or less.

2) Technology Overview:

The Gardena SILENO Life comes as a compact device with dimensions of 22.8x15.4x9.1 in and packs in many great features:

a. Microprocessor
b. Ultrasonic sensors
c. Thermal sensor
d. Stop button
e. Monochrome graphical
f. Lithium-ion battery
g. 3 angling mower blades
h. 4 wheels
i. WiFi/Bluetooth transceiver
j. Blade angling motors
k. Wheel motor

3) System Description:

As depicted in Fig. 8., the boundary wires sensed by the mower's sensor set as well as user input through the app are passed through the microprocessor. The user may also choose to use the emergency shut off which will disengage the mower regardless. Within the mower, the microprocessor evaluates data from the sensors and the user and maintains the mowing activity as long as there is battery life to sustain it and the conditions are favorable enough to do so. The thermal sensor detects when the surrounding temperatures are sub-freezing and delay mowing until the weather warms again. Obstacle avoidance is implemented with the sensors on the device to detect objects in front of the mower, and the processor uses an algorithm to calculate the best path for the device to avoid a collision. The monochrome display is fed data by the microprocessor as well. The mower is recharged by the charging dock which also sends a signal down the boundary wires to make them detectable to the ultrasonic sensors.

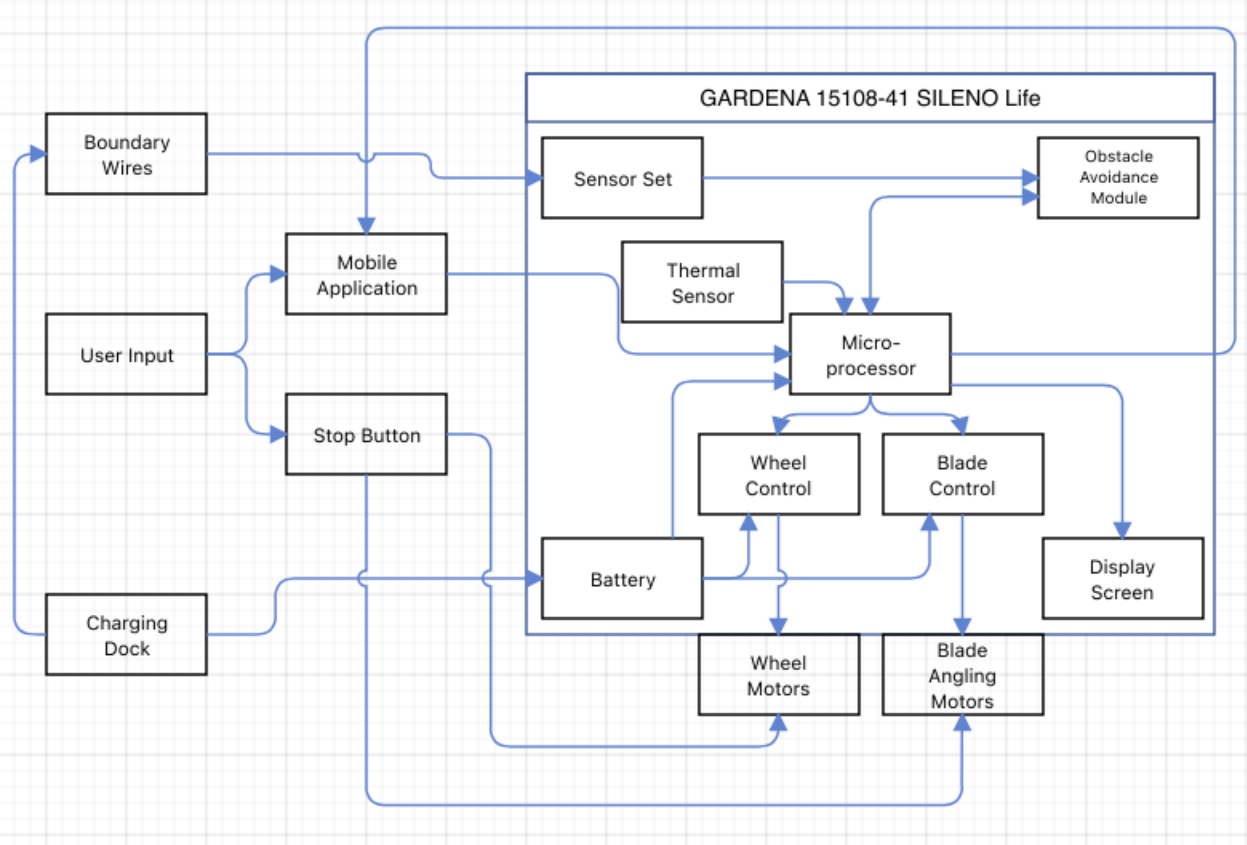


Fig. 8. Block diagram of the GARDENA 15108-41 SILENO Life

The Gardena SILENO Life is a competent and refined iteration of autonomous lawn care technology combining many of the best features from mower both above and below its price point and eliminating unneeded bulk. This project should embody that same goal of intentionality and simplicity so as to achieve the objective of being affordable and useable. At the same time, mowing in the rain presents unnecessary challenges in chassis design and the potential for wet clippings to clump and pile in unsightly ways, so this project will aim to improve upon the existing weather-smart features (such as frost detection) by avoiding unfavorable conditions of all kinds as much as possible.

Having reviewed these three products, it is clear that the fundamental technologies of boundary wires, connectivity, battery capacity, and motor efficiency will be of the utmost importance in achieving an effective design. The main challenge common to the three of them is creating a mower that can maintain a medium- to large- sized lawn without pricing most consumers out of the market. Our design aims to solve that problem by emphasizing intelligent and efficient use of existing sensors without expending capital on expensive components that do not greatly impact the performance of the device such as sophisticated GPS systems.

IX. INTELLECTUAL PROPERTY

Intellectual Property is intangible property that includes inventions, designs, brand names, and any artistic work. Patents, copyrights, trade secrets, and trademarks which fall under intellectual property, and are granted by the United States Government and protected by law. Patents protect others from making, using, selling, and importing an invention protected under a patent. With this, it is of vast importance while researching previous comparable designs before a designer developing a particular invention. Thorough research will be of great interest to the designer to hinder lawsuits on the plan due to patent infringement.

While researching current patents, our team will assess three patents that closely relate to our project and are all filed with the United States Patent and Trademark Office. The patents include *Autonomous Lawn Mower and a System for Navigation Thereof, Autonomous Lawn Mower,* and *Lawn Mower Robot.* Our team acquired these patents using the Google Patents search engine and the United States Patent and Trademark Office database. The end goal was to become aware of current patents related to our design.

A. Autonomous Lawn Mower – US 20170181375A1

The inventors of this patent were Takeshi Hashimoto, Susumu Okubo, and Kenta Kawanishi, which relates to our design of the Autonomous Lawn Mower. The patent was granted on October 23, 2018, and will be described in the following sections below.

1. Summary

This patent has an array of implementations that relate to the physical design attributes of our Autonomous Lawn Mower design itself, including the way of operation. This patent aims to design an autonomous lawn mower utilizing an electrical function and a manual method with a low production cost. It will have a traveling frame with wheels to travel attached to the frame. It will also include a motor holding member on the traveling frame for the traveling wheels, and the device will have four traveling wheels in total shown in Fig. 9 [3].

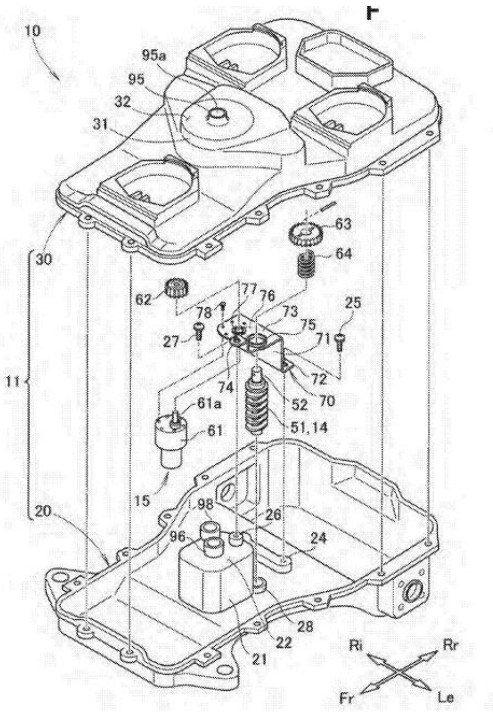


Fig. 9. Represents the exploded view including the traveling frame and where the traveling wheels attach [3].

2. Claims Summary

This patent has a total of two claims. The ones related to our project are:

A. A traveling frame with four wheels, a member for holding the cutting blade motor, and the motor for the cutting blade.

3. *Non Infringement*

Although this patent relates closely to the physical design factors of our project, we will not be infringing the designs of this patent. We will be scheming a different way to support the blade, motors, wheels, and all other parts of our Autonomous Lawn Mower. If needed, a different traveling frame will be designed to support all components. Our design will have four wheels but will be located outside the body for propulsion.

B. Autonomous Lawn Mower and a System For Navigation Thereof - US011172608B2

The inventors of this patent are Klaus Hahn, Todd Brandon Rickey, Benjamin Rickey, and Edgar Montgomery, and it relates to the design and navigation of the Autonomous Lawn Mower.

This patent was granted on November 16th, 2021, and will be described in the following sections below.

- *Summary*

This invention is related to the design and navigation system of the Autonomous Lawn Mower. The device has multiple hardware devices, including a LiDAR unit, sonar sensors, wheel sensors, two motors, and a CPU. It also includes modules to run the various types of sensors. A GPS device is installed onto the device, so exact locations already trimmed will be saved. The layout of all the components is shown in Fig. 10 [4].

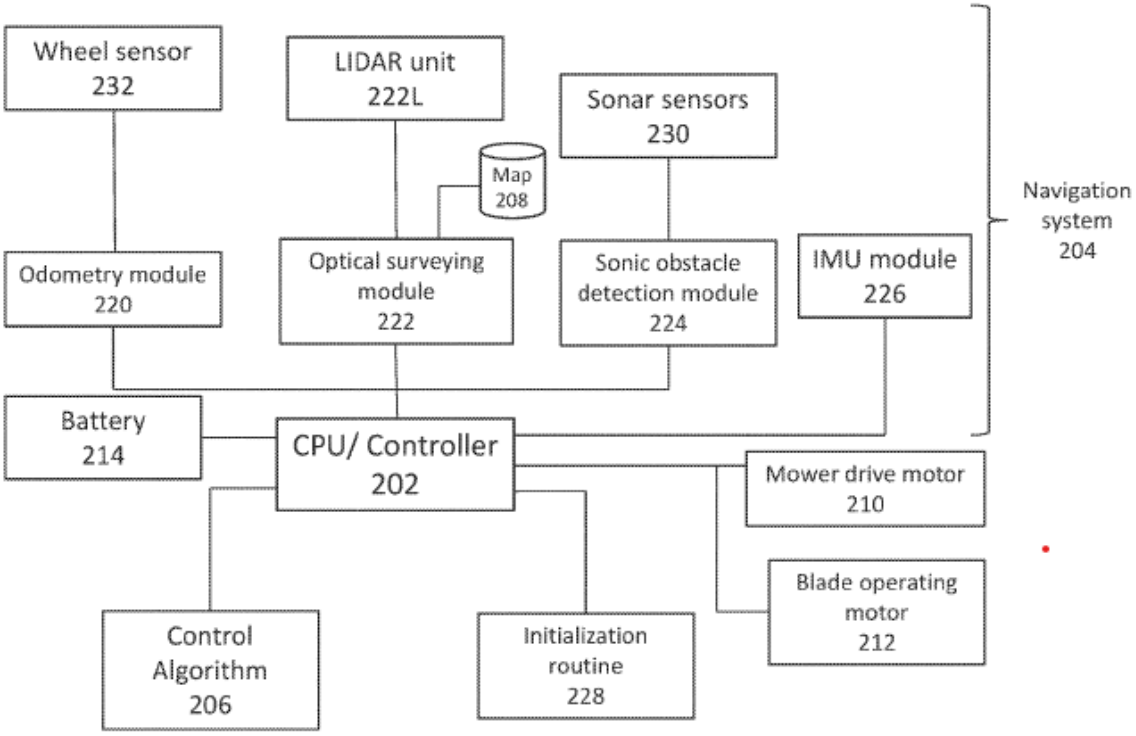


Fig. 10. A layout of all the hardware components including the battery, motors, modules, sensors and storage of the map [4].

GPS will detect the cutting area of the device, thus allowing the device to stay within the perimeter of the yard and prevent it from wandering off and trimming neighboring yards. The device will have edge-cutting technology aside from the main cutting blade to assist in cutting the edges around areas like the perimeter of the house and fencing surrounding the yard.

- *Claims Summary*

The patent has a total of fourteen claims. The ones explicitly related to our project include the following:

- A navigational system included in the mower body to aid the controller in controlling the mower within predetermined areas of operation.

- The mower will include a cutter module aside from the main cutting blade which will trim the edges of the lawn.

- *Non Infringement*

The patent covers the navigational system and specific features of the product. The navigational system is very similar to our design. However, our design will not have a predetermined path set in place. It will follow a very distinct cutting pattern to cover all areas of its surrounding, turning or attempting to go around obstacles when detected until it reaches the perimeter, then turning 90-180 degrees to resume mowing in an alternate direction. The path will not be predetermined and may go in different directions during every use. But the algorithm programmed into the device will select the best possible approaches based on situations like detecting perimeter sensors and obstacles. Our mower design will not include edge-cutting services. Instead, it will go as close to the edge as possible and trim utilizing the primary blade.

C. Lawn Mower Robot - US011096325B2

The inventors of this patent were Hyunsup Song and Changhyeon Lee, which relates to our design of the Autonomous Lawn Mower. The patent was granted on August 24th, 2021. It will be described in the following sections below.

1. *Summary*

This patent has multiple implementations related to our Autonomous Lawn Mower design, specifically the safety and feature designs of the device. The device will replace traditional lawn mowers like push lawnmowers and lawn tractors. The plan intends to be a fully automated lawn mower with minimal user interaction. It will have castor wheels along the front sides of the device to aid in lifting and lowering the mower depending upon the terrain and obstacles shown in Fig. 11 [5].

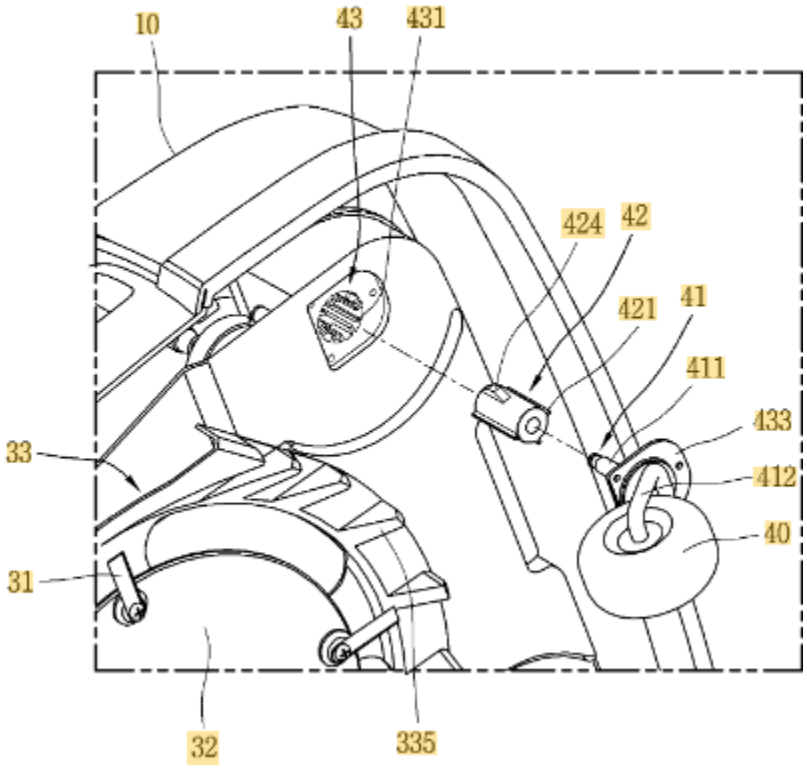


Fig. 11. A diagram of the castor wheel locations and installation [5].

The device will also have various types of prevention for accidents, like preventive covers to avoid injuries to hands and feet. It will have a bumper portion to protect the mower from obstacle collisions. A carrying handle will also be equipped to move the mower around quickly.

2. Claims Summary

The patent has a total of 20 claims, the ones related specifically to our project includes:

- The lawn mower robot will have castors close to the front side of the inner body of the device. It will also have support to assist in holding the outer top cover.

- The lawn mower robot will use ultrasonic sensors to detect the slope of the yard. This will be used when the device is propelling downhill to reduce the speed of the device.

- The device will have a keypad along with a display for controlling the device.

3. *Non Infringement*

This patent focuses on supporting the cover and the locations of the castor wheels and using ultrasonic sensors to detect downward slopes to adjust the device's speed. It also includes a display and keypad for critical information and control. Our team will not be infringing on this patent since our device's castor wheel will be located directly to the front of the device. Our Autonomous Lawn Mower will use ultrasonic sensors differently. Rather than being used for slope detection, it will strictly be used for obstacle detection and avoidance with an algorithm programmed into the device. Our device also will be strictly app controlled. All critical information will be displayed in the app rather than on the device screen itself

X. GLOBALIZATION

A product as intuitive, effective, and globally accessible as the Autonomous Lawn Mower and its planned vision resembles how major products came into existence, such as autonomous vehicles and PayPal; Autonomous Lawn Mower will be the equivalent of this generation's intuitive technological innovation. We will succeed globally because we reach an important niche and demographic. The first criterion often satisfied and stressed while making a product as engineers is the design and manufacture of the product, which usually relies on the theoretical approach and the actual hardware components. Any design must consider the technical specifications, although this is sometimes misinterpreted as the most crucial element. The demands a product fulfills are, in theory, its most crucial feature, especially in today's market and economy. To set the necessary worldwide standards, globalization is introduced at this point. A product must satisfy a worldwide market that wants to be successful across all hemispheres, which means it must meet the international standards of catering to various demographics. A successful product must satisfy a universal standard that applies to many different nations and the requirements of each market. Aside from meeting technical requirements, the design team aims to conform to the World Trade Organization (WTO) requirements and the International Organization of Standardization (ISO). Adhering to these guidelines can assist assure product success in the worldwide market.

For the ISO, the standards the Autonomous Lawn Mower will focus on are the ISO 14000 and ISO 50001 families. The first focuses on environmental management with the need for practical tools to manage environmental responsibilities. The latest one is oriented to energy management to address the conservation of resources and improve efficient energy management. Compelling with both of these will make us more apparel to foreign markets.

Any product can benefit from a local following, but those with a worldwide following stand out as the most useful. While brands like Meta may have originated locally in the United States, they now have a worldwide presence that extends to other nations and organizations. Factors like those listed above demonstrate the importance of creating a multidimensional and sustainable product across many demographics. An engineering product should ideally strive to achieve global acceptability, which means that the product is essential to society and has a significant utility. The autonomous lawn mower is an effort to make autonomous manage the lawn accessible to everyone. It applies to the global level since it plans to become one of the leaders in robotics. A product like ours will try to adhere to the correct global conscious beliefs of the twenty-first century.

The goal of producing a product that is both competitive and capable of becoming a success on a worldwide scale necessitates compliance with several crucial rules and standards. The autonomous lawn mower will give the user the appropriate safety instructions for usage, according to the specific power requirements based on the nations being targeted, in order to achieve these criteria. The distinguishing characteristics of the Autonomous Lawn Mower include its ability to cut lawns while also being portable and using little power. Lower power usage is a crucial characteristic made possible by voltage and power laws in many nations. The autonomous lawn mower must first fulfill the minimum requirements, then it must be portable so that it can be used easily and moved about.

The global perspective needs the Autonomous Lawn Mower cores aspect to be satisfied. These are the power to charge the battery, the data for the navigation system, and the radio frequency. We have to consider everything on local, national, and international levels. In the ISM bands, Bluetooth uses UHF radio waves between 2.402 GHz and 2.48 GHz.[6] The standards comply at an international level with IEEE 802.11. IEEE 802.11 operates at various frequencies, including the 2.4 GHz, 5 GHz, 6 GHz, and 60 GHz bands. Even though the IEEE 802.11 specifications list possible channels, the permitted radio frequency spectrum availability varies significantly by regulatory domain. In the United States, jurisdiction over energy and electricity interconnection is divided into two distinct levels of governance: federal and state authority. The Federal Energy Regulatory Commission (FERC) has authority over all interstate and wholesale electricity commerce at the national level. States have jurisdiction over intrastate interconnections but have limited authority over facilities that provide services across state lines or participate in interstate wholesale electricity markets.

1. World Trade Organization

The World Trade Organization, WTO, offers a platform for negotiating agreements to remove barriers to international commerce and guarantee equal playing conditions for all, promoting economic growth and development.[1] The WTO also offers a legal and administrative framework for carrying out, overseeing, and resolving disputes relating to interpreting and enforcing these accords. 16 distinct multilateral agreements, to which all WTO members are participants, and two separate plurilateral agreements make up the WTO's current corpus of trade accords (to which only some WTO members are parties).

Intellectual property, products, and services are all covered under WTO accords. They outline the liberalization's guiding principles as well as its acceptable deviations. They include each nation's pledge to establish and maintain open services markets and cut customs duties and other trade obstacles.[4] They establish protocols for resolving conflicts. These agreements are not permanent; they are periodically renegotiated, and further agreements may be included in the bundle. The Doha Development Agenda was introduced by WTO trade ministers in Doha, Qatar, in November 2001 and is now the subject of several negotiations.

The WTO has principles they use to make decisions. It should go without saying that lowering trade barriers, which include tariffs and measures like import bans and quotas that impose quantity restrictions selectively, will promote trade.[3] Also, foreign businesses, investors, and governments should believe that trade obstacles will be unrestricted. Investment is encouraged, jobs are generated, and consumers may enjoy competitive advantages, such as more choices and cheaper costs, with stability and predictability. The Autonomous Lawn Mower needs protection to compete in international markets to gain momentum and be successful. Without WTO, this would be impossible for us.

2. Trading Barriers

Global limitations don’t let a product mature. It limits their potential to the local population putting a cap on how much yield they can contribute to society. Trade restrictions make it impossible to disseminate goods globally. Lowering trade barriers is one of the methods to achieve proper globalization. The most excellent approach to removing trade obstacles is through standards. The requirement to adhere to the numerous foreign technical norms and standards that act as trade barriers is one of the critical components of dealing with the WTO. Regulations specify a product's particular requirements, including those related to its size, shape, design, functionality, performance, and even how it will be packaged. The difficulty lies in the fact that many countries have various technical laws and conformity evaluation processes. For a product to be sold in that nation, it must be able to adhere to all of its regulations.

Companies can’t operate abroad whenever they want to. There are requirements to ensure a product meet certain minimum qualities and safety levels. Those minimums are established by the International Organization for Standardization, in which various experts in each field give specific recommendations in each area. The reason behind these requirements is to promote a good cause for the well-being of the consumers and the overall population country. It frequently refers to an accepted method of doing something or a resolution to a major issue.[5] Following the ISO guidelines will increase Autonomous Lawn Mower acceptance internationally.

3. Collaboration Tools

Designers need to be able to communicate, and doing so successfully is a crucial step in the process. Every team member will only sometimes be available, so having a mechanism to communicate across national boundaries or the globe is essential. The design team used two different kinds of communication in this case after selecting and discussing tools. One type of communication requires access through a smartphone platform, but the other allows for communication on a PC, phone, or any other device that can run the Zoom software. Due to contemporary technology, the design team determined WhatsApp and Zoom would be the two ways of communication.

Communication, documentation, and data display are a few collaboration technologies' purposes. The primary file-sharing tools were Google Drive and GitHub, allowing any team engineer to create and see a repository. The other tools utilized are for communication. For example, WhatsApp is a secure encrypted tool used worldwide for chats, enabling you to host a group of people and have the capacity to call; all you need is a phone or a wi-fi network. Zoom is a comparable program that allows for speaking and communicating over the phone and on a laptop or PC. It also typically hosts files for rapid file sharing on the move for tiny concepts, whereas Google Drive is best utilized for larger files and entities. A free universal method for everyone to use the same media platform and share files, create PowerPoint, or create google documents, Google Drive has access to the desired Google Docs. The ideal way to utilize these apps is sequential, with Google Docs and WhatsApp being used immediately and Zoom being used if the other tools are unavailable or for simpler, more straightforward tasks.

4. International Success

The Autonomous Lawn Mower conception gave rise to a significant and expanding global concept. The Autonomous Lawn Mower will be successful internationally because it complies with international standards, is a genuinely innovative product, and addresses a crucial issue in contemporary society: accessible autonomous lawn mower robots for everyone. Worldwide success must consider a range of other markets and determine how the product may be used in a completely other culture. In this case, the design team chose to privately discuss the predicted demand for the product as well as how the product would operate with a wide range of students from various nations. The Autonomous Lawn Mower is a robot based on an autonomous navigation system and edge technology so our users can effectively focus on what matters the most.

One of the team members, Michael Szerman, went to Boston for a couple of months. He got the opportunity to talk with people from all over the world and discuss the culture with a saleswoman from Japan and an MBA college student from Puerto Rico.

Erica Yamamoto is a phycologist for Mei Physocology. She told us that Japanese popular culture offers a link to the past in addition to reflecting attitudes and concerns of the present. Many subjects and presentational techniques used in popular movies, television shows, comics, music, anime, and video games have roots in ancient literary and creative traditions. When Erica was asked her thoughts about the Autonomous Lawn Mower, she emphasized that Japanese work over twelve hours per week, so they don't have time to take care of their lawn. It would be convenient to have that taken care of for a low price.

Darrius Sanches is an MBA student doing a coop at Dell. He's from Puerto Rico. When asked about the Autonomous Lawn Mower, he was skeptical of how the people from Puerto Rico would integrate the device. He gave us the insight that the culture in Puerto Rico doesn't adapt to the latest technologies since they prefer to live a more pre-industrialization lifestyle. Technologies have a hard time being incorporated. A robot, already futuristic compared to other innovations, won't be accepted with open arms. So the odds of success there aren't in our favor.

International success refers to reaching the essential demographics in global marketplaces, which we can do while upholding the principles of globalization. We can join the international market and successfully work toward success there if we plan carefully.

XI. STANDARDS CONSIDERATIONS

Standards are, generally speaking, agree upon codes of design to which products may be voluntarily subject to increase cross-compatibility and uniformity between different products of a similar nature. There is no shortage of standards organizations promulgating different design specifications to be observed. There are many national organizations; for example, in the United States of America there is the ANSI also known as the "American National Standards Institute" which is the main standards body for the country. Beyond that however, there are also international standards that coordinate design on a global scale. These are managed by such organizations as the IEC (International Electrotechnical Commission) and function very similarly to ANSI and others.

The major drawback to centralized standard management is that it is its own business of sorts wherein these documents cost time (and therefore money) to draft, approve, and manage, and thus access to them is tightly restricted pending payment of whatever fee that parent organization deems appropriate. Having (1), reviewed the history surrounding the relevant standard applicable to robotic lawnmowers such as the one set forth in this proposal (ANSI/OPEI 60335-2-107-2020) and seeing that the relevant standard has only just been introduced under 2 years ago, and (2), weighed the cost of accessing such a document for review to see its requirements thereby to investigate its potential benefits relative to its costs and having assessed the document's cost alone to be several hundreds of dollars (potentially exceed that of $1,000 per part depending on the issuing authority and the revision) we have determined that it is in the best interest of the project to forego formal standardization in an effort to minimize R&D costs and allow flexibility in the product development to better achieve the customer needs and constraints set forth elsewhere in this proposal.

XII. Health and Safety

Health and Safety plays a vital role in the design of the Autonomous Lawn Mower. It will most certainly determine the success of not just all future designs but specifically the design of the mower. Avoiding any health or safety issues with the design is a required part of the design. This includes circumventing any detrimental side effects and possible injuries. Per the World Health Organization (WHO), "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. An important implication of this definition is that mental health is more than just the absence of mental disorders or disabilities [28]." It is of utmost importance to the team to prevent any possible injuries and illnesses with the design of the Autonomous Lawn Mower. Adhering to the recommendations of the World Health Organization will ensure the team does not knowingly design a product that will cause harm in any possible way.

A. Health Safety and E-Waste

Proper health regulations and safety must be considered for any design, including the Autonomous Lawn Mower. Senior Design Team 16 must create an autonomous lawn mower that is safe to use within any environment including around humans and animals such as pets. The design must also be free of any health risks the design can possibly pose. The quality of life is a top priority for Senior Design Team 16. Safety is taken into consideration for all stakeholders including designers, clients, employees handling and/or repairing the product, and the final users. The design will not include any known hazardous materials. Any material known to be threatening will not be used in the design for the sake of safety for all people handling the product. To prevent accidental use of hazardous materials, all materials and components used in the design will be Restriction of Hazardous Substances (RoHS) compliant. Using items that are compliant with the RoHS will ensure the safety of all stakeholders who will be handling the product. It will also ensure the safety of the environment and surroundings that the mower will operate.

At this day and age, many people are concerned with privacy issues with technology. The advancement of technology has grown to be extremely vast that data collection is a must for many companies like Google and Amazon. Although the Autonomous Lawn Mower can be connected wirelessly, all information collected like mapping of the lawn and obstructions detected will be stored locally on the storage device of the mower and will not be accessible by anyone. No credit card data or financial information will be needed for operation or to unlock any features. All features will be provided with the purchase of the mower. Certain data safety protection will be implemented to ensure the peace of mind of the user. There will be no other data shared over the internet other than starting, stopping or an obstruction of the mower.

Electronic waste or E-waste is “any electronic component that is or will soon be at the end of its useful life [29].” Some examples of E-Waste are old televisions, laptops, and cellphones. The Autonomous Lawn Mower will produce quite a low amount of E-Waste. The main component is a Raspberry Pi which is so small. This will help with a reduced amount of E-Waste. The lithium-ion battery will provide the most amount of E-Waste within the design. This will be taken into consideration by the team. To help reduce this, the team plans on partnering with a provider who

provides E-Waste recycling to offer an incentive when the consumer does recycle the lithium-ion battery. The user needs to provide the serial number to the recycling program, then an incentive will be given in a gift card provided by the manufacturer. The incentive will help promote proper recycling of the battery when it does need to be changed. This will help protect the environment from any harm if the user just decides to throw the battery in the regular curbside trash collection. Any persons who are approved to repair the product must also properly dispose of the battery. The manufacturer will require receipt upon recycling the battery. If the repairer does not provide receipt after two change outs of the battery, they will be removed from the authorized repair listing. This will ensure that the lithium-ion batteries are being disposed of in accordance with the Environmental Protection Agency (EPA).

B. Liabilities

A liability can be defined as the state of being responsible for something. In the team's case, liable for the Autonomous Lawn Mower and any possible harm the quality of life. Senior Design Team 16 is hereby liable for any issues that can arise from the Autonomous Lawn Mower. This includes bodily harm from the mower when handling as advised and any illnesses from materials used in the mower. The team will make certain that device does adhere to all laws to protect all stakeholders. The team does not want anyone to be injured in anyway due to the Autonomous Lawn Mower. If any unknown issues occur, the team will issue proper liability concerns if this does happen. The team will attempt to completely remove all harm and risks related to the mower before production for consumer use. Strict rules set in place by the American Law institute will be followed as well to protect all stake holders. The strict tort liability that will be adhered are as followed:

(1) One who sells any product in a defective condition unreasonably dangerous to the user or consumer or his property is subject to liability for physical harm thereby caused to the ultimate user or consumer, or his property, if

(a) the seller is engaged in the business of selling such a product, and

(b) it is expected to and does reach the user or consumer without substantial change in the condition in which it is sold.

(2) The rule stated in Subsection (1) applies although

(a) the seller has exercised all possible care in the preparation and sale of his product, and

(b) the user or consumer has not bought the product from or entered into any contractual relation with the seller.

With the information above, it offers a course of action and liability concerns with any product design and production. A contract with the stakeholders that stating the product will not cause harm to any persons or the surrounding environment that the mower will operate in in accordance with the above strict tort liabilities is important. This will provide success for the Autonomous Lawn Mower since it is offering active liability for the team's design.

The Autonomous Lawn Mower designed and created by Senior Design Team 16 is an attempt to create a fully automated lawn mower with minimal user interaction. Although a lawn mower can be a very dangerous object when used incorrectly, the design must still be free of flaws that can cause harm. Safety and the health of all handlers is the most important aspect of the team when considering this design. Creating this design with safety as a top priority is important for the team. Having a harmless design will make certain all users are safe when operating the equipment.

XIII. Environmental Considerations

The world is a single one. There are no second chances to repair the damage made to it. The main driver of the development of the world's health is the environment. That's why in the last decades' governments and companies have focused on measures and technological advancement to protect it. It's well-known, based on scientific research, that global warming is real. All engineers must be aware and aim to propose solutions for their product development that won't harass the environment. There's the risk of products not considered environmentally friendly to never reach the product market. Consumers are becoming educated on the subject and so limiting their consumption to products that follow standard procedures that are environmentally friendly. If the development and manufacturability of the Robot Lawn Mower don't follow the standards considerations, we would be putting at risk the profitability of the product.

Having said the importance of being environmentally friendly, we have created a plan to ensure this. The team behind the Robot Lawn Mower is well conscious of the issue. The robot product will generate as little electronic waste as possible, we may be able to achieve zero e-waste given the correct conditions. With the correct blades and sucking system, the robot can store all the cut grass inside a vacuum to reduce the stress of littering on the lawns. The Robot Lawn Mower will contribute to environmental preservation and lessen the overall impact of having messy lawns all over the world. To achieve this we will apply the RoHS directives, focus on easy disassembly, make the component selections based on Life Cycle Impact Assessment, and adhere to some of the Hannover Principles.

A. *Restriction of Hazardous Substances Directive (RoHS)*

A growing amount of electrical and electronic waste has been produced due to the increased manufacturing and usage of electrical and electronic items, including kitchen appliances, laptops, and mobile phones. Products may produce dangerous (hazardous) compounds, including lead, mercury, and cadmium, during the use, collection, treatment, and disposal of such waste, which can seriously adversely affect the environment and human health. The EU has been proposing regulations to restrict the use of dangerous chemicals in response to such issues. Although the directives are applied to Europe Union state members, there are some implementations in the U.S., such as in California, it's a good guideline to practice for any team worldwide.

The RoHS directive 2002/95/EC was established by the European Union on January 27th, 2003, and forbids the use of hazardous compounds in products. Shortly after, the 2002/96/EC directive was also established to formally set electronic device collection, recycling, and recovery targets. There were six substances banned by now until, with the RoHS 2 amendment, the 2011/65/EU directive[30], four more substances were added to the list. The RoHS regulations prohibit the usage of the following:

A. Cadmium (Cd)

B. Lead (Pb)
C. Mercury (Hg)
D. Hexavalent Chromium (Cr VI)
E. Polybrominated Biphenyls (PBB)
F. Polybrominated Diphenyl Ethers (PBDE)
G. Bis(2-Ethylhexyl) phthalate (DEHP)
H. Benzyl butyl phthalate (BBP)
I. Dibutyl phthalate (DBP)
J. Diisobutyl phthalate (DIBP)

The substances aren't forbidden in tiny concentrations. For Cadmium, the maximum allowed concentration is 0.01%, while for the rest of the substances is 0.1%.

B. ***Ease of Disassembly***

The Robot Lawn Mower is easy to install on any lawn, apartment, or home. The device is installed by placing the rechargeable solar panel-driven mini-storage of the robot on the lawn and placing the robot inside it on the charger. Once the robot bootups, you need to configure the one-time settings with our app. The disassembly consists of two parts: the use disassembly and the manufacturer disassembly. Previously we explained the disassembly property from a user perspective. The manufacturer can dismantle the product by unscrewing it. Then the manufacturer can remove the parts keeping the gadget together to expose every component. The pieces can all be removed after they have all been made visible. Any device should have an easy disassembly process since it can aid users in understanding how the product operates and its internal circuitry and facilitates it restoration or recycling process.

C. ***Hannover Principles***

The Hannover Principles, created by William McDonough and Michael Braungart[31], were among the first to comprehensively address the fundamental concepts of sustainability and the built environment. They acknowledged our interdependence with nature and proposed a new relationship that includes our duties to protect it. The Principles inspire everyone to reconcile long-term sustainability issues with ethical responsibility and to re-establish the essential connection between natural processes and human activity. This includes you, your business, your suppliers, and your consumers. For this importance, the Robot Lawn Mower's team decided to comply with the following principles:

- *Rely on Natural Energy Flow*. The power required by the robot to function appropriately will come from natural sources. The battery is charged from energy drawn

from a solar panel. This way, we adhere to the design principle, deriving their creative force from perpetual solar income like any other living thing.

- *Understand the limitation of design.* All the components from the robot are prepared to be replaceable in the case of failure. It's also designed to upgrade each piece independently, similar to building with legos, where you can replace each block independently from the other. The idea behind this is for us to accept that no design last forever, and we should plan ahead with humility to accept the flow of nature.
- *Seek constant improvement by the sharing of knowledge.* We will constantly talk with other engineer peers, mentors, and curious people during the development. For the software and hardware development, lessons learned will be shared on online forums to receive feedback and thrust the community. With the open loop of constant feedback, we can improve our designs and become better engineers to deliver our clients a better product.

D. *Life Cycle Impact Assessment (LCIA)*

Engineers utilize the Life Cycle Impact Assessment (LCIA) to evaluate the environmental impact a product will have, from selecting its components until the product is assembled and put to use by a user. This method evaluates the effects the product will have throughout distribution, repair, and maintenance activities[32]. The LCIA will compile a list of every item employed in producing a good and assess each according to its possible environmental effect. To ensure their product won't have a detrimental influence on the environment, engineers will employ the LCIA as soon as they start collecting resources for a product. The LCIA is a flawed evaluation. This is because a lack of data prevents the LCIA from calculating the harm a product could do to an environment. The LCIA will try to ascertain the environmental effect but cannot estimate the level of harm a new product may inflict on an ecosystem due to a lack of data. Despite these drawbacks, engineers frequently employ the LCIA to guarantee that their creations will positively influence the environment.

In conclusion, the engineers developing the Robot Lawn Mower take the environment seriously. We went over the main reason why considering the environment from the initial building of a product is essential for how design decisions are made. After, we review four techniques, principles, and perspectives on tackling all the environment-friendly requirements using the RoHS directive, Ease of Disassembly, Hannover Principles, and Life Cycle Impact Assessment.

XIV. Sustainability Considerations

It is important when designing products of quality that satisfy the vision of the "good life" to bear in mind certain future considerations that are relevant to customers and any other stakeholders there may be. These considerations may be concentrated principally internally—that is to say, with respect to the product itself—or externally—that is, with respect to the device's wider impact beyond its obvious use case.

In the case of this autonomous lawnmower, both external and internal considerations are of paramount importance as we want to provide a quality product to customers that will not have any avoidable negative consequences on users or their environment from day one until it becomes time for the device to be retired. This is one of the many reasons that we have placed an emphasis on excluding unnecessary components that bulk up the device and ultimately will result in more electronic waste in the environment, junk yards, and other places of that ilk. Also, with a streamlined design comes reduced complexity, and since complexity and reliability are, generally speaking, inversely proportional to one another, decreasing complexity means increased reliability and therefore longer-term value to the customer and the environment. On the flip side, to provide a sloppily designed and sloppily constructed device would be: 1) to consume unneeded amounts of valuable raw materials, 2) produce greater than necessary amounts of waste, and 3) to ensure a shorter lifetime of the device and thus decreased value to the customer and increased overall consumption of the aforementioned materials.

Yet again, sustainability concerns show themselves to be another profitable (in more ways than only fiscal) result of streamlined, conscientious design and fabrication. Manufacturability decreases environmental output and increases built quality, as does minimality in design limiting the device to only that which is necessary to intelligently accomplish the project's function and constraints. Our mower's sustainable lifecycle will prove to be beneficial for all stakeholders for all generations to come.

XV. MANUFACTURABILITY CONSIDERATIONS

This section will be about the importance of manufacturing considerations in our design process. Many considerations were made in the beginning to reduce design cost and time to market the product. One of the most important things is talking with the client to get their approval. Trough clients recommendation we added certain design changes and possibilities for the product. In this section, four major components will be listed which will be available and easily built once the finalization of the design is done With the final design being done at the end of senior design 2, the product can be easily and quickly recreated in less time for mass production.

The first component is the motor controllers. The motor controller is a piece of circuitry that will control the speed and directions of motors. For this component, the L298N dual H-bridge motor driver will be used. It's quick and easy to order from amazon while also being cheap. Assembly of the component is straightforward and taking no longer then a few minutes. The component is safe and reliable with countless resources online for troubleshooting and configurations. Manually designing the component will take countless hours and prototyping to get it functioning to our desired specifications. This essentially saves a lot of precious hours or days in the design process and lets the team focus on the other aspects of the design.

The second component will be the body of the robot. The body is an essential part of the robotic mower and is what makes the product durable and protects the inner components. Finding a body or making one with consistent design specification will be a difficult task and one that is time consuming and can't be mass produced easily. Designing by hand will take additional resources such nuts, bolts, adhesives and body material. This is why the team went with the choice of designing the body in 3D designing software such as fusuion360. With a designed finalized in 3D software, the body can be printed and produced countless time with the exact specifications while also costing less since only one material is used for the overall body. Also if any changes are required, they can be quickly edited in software and reprinted. This essentially saves the team time when it comes to the production of the body and mass production of the part will be easier too.

The third component is the microcontroller itself. The microcontroller is the brains of the whole product. It's important to take into consideration of a proper microcontroller that meets all the specification of a design. The team decided to go with the Arduino UNO for this product as compared to other microcontroller, its powerful and has many more capabilities beyond the scope of the product. It will allow easy implementation of additional upgrades in the future such as additional sensors and software upgrades like machine learning capabilities; all of this will be done without changing the final design and hindering manufacturing progress.

The fourth component is the mower blade itself. Rather than reinventing the wheel, the team went with generic mower blades that are easily available in hardware store such as Lowes, Home Depot, and Harbor Freight. Constant prototyping of the blades and testing for best functionality will be a waste of time and resources when there are blades that are readily available with the guaranteed of functionality. It will be also easy on the manufacturing process and customers them self, as the blades can be ordered form a vendor and quickly assembled.

Overall, the whole product components have symmetrical elements and giving the whole product itself a very symmetrical design. Taking into consideration of the components, the whole manufacturing of the product should be very efficient while inexpensive. With the motor diver, microcontroller, and Baldes readily available from vendors; the assembly process shouldn't be difficult or time consuming and especially with the wide range of data available on these components. The microcontroller itself has wider capabilities then needed and for the future can easily implement upgrades without hindering manufacturing. The body itself might be the slowest part of the manufacturing, but with a single deign to follow,it can be mass produced with great accuracy and costing less to build.

XVI. Ethical Considerations and Social Impact

When we considered building our project a question was asked “will our project help people” this question led our group to the desired machine that would aid in a task that is done by 228.73 million Americans [8]. Our objective when creating our robotic lawnmower was simple: create a machine that can assist in helping people around the world. The designs while in the early stages of development are carefully constructed in compliance with the IEEE code. This is to make sure that our robotic lawnmower causes no harm and maintains the highest standards of integrity within our creative process. Furthermore, the Theory Model will resolve any decisions or designs that cannot be directly addressed by the IEEE code of ethics. This is to ensure that in any event of oversight we can ensure that our project is within the guidelines. Our ability to ensure that our product can indeed follow the guidelines of the IEEE code is of the utmost importance however in the pursuit of compliance with the IEEE we realized that there were ethical dilemmas that affected our ability to be completely dedicated to the IEEE code. When we realized this, it became paramount to amend these dilemmas with the Theory Model.

A. Ethical Considerations

We hold our product's ability to align with the IEEE code of conduct with the highest regard when constructing our project. A few stood by initially before we even began to glance at the IEEE code. Keep in mind that our project follows the rules and regulations stated within the IEEE code but the ones under great consideration were as follows. To paraphrase the safety and welfare of the public with gusto to comply with an ethical design. For our group, our top priority is to ensure that if this product were to be commercialized and delivered to people, our biggest concern would be the safety of those that would be receiving our product. Our product when delivered or store-bought would require little to no attention by the purchaser. Our goal is to ensure that the customer's troubles with their lawn care are minor problems that are easily fixed by our product's reliability, convenience, and simplicity. With these in mind, our group has focused on avoiding internal issues with each other. More specifically, a conflict of interest was immediately dealt with in the development of this project. This is something that usually plagues companies that began with a plan but do not converse with one another for large amounts of time. We were able to solve this with weekly meetings to continue at maximum capacity and without any conflict. Among these Codes of Ethics, there was one that stood out from the rest because for our group it is something that we all shared, and that was the ability to be critical. Our ability to ensure that our critiques of other work were going, to be honest, and constructive was the reason why we can work well with each other. We were able to maintain honesty and constructiveness because of our ability to abide by these Codes of Ethics, and we will continue to abide by them from this project to the next.

Our ethical dilemma when constructing our project was our device’s ability to recognize objects and people when cutting grass. When constructing our device, we realized that if our lawn mower would come across something that doesn’t have grass what would happen? If it can’t stop until the job is complete or if our device is not able to continue with the task because of this object

it would lead to harm. Although our device would be able to cut the lawn and get the job done, it would need to be under the circumstance that no one or anything would be in the way. Our dilemma is that we can create a device to do its job but only under strict circumstances can the job be done unless the customer would risk a bird or someone being caught in the process.

As a team, we devised solutions that may accommodate the user when running into these problems. Option one would be to install sensors within the machine so that it may detect people around them. It will then power down so that it cannot cut grass and move around the object. This option would come into play after the device is released, free of charge and installation. The second option would be to have a kill switch within the device. With this, we can ensure that the device when coming across objects would be able to deactivate and do no harm to the object or person. The third solution would be to have a device that sends a warning to the customer notifying them of an object in front of them. Although this seems like option one the difference is the task of manually going outside and attending to the situation, this would defeat some of the purposes of a self-automated grass-cutting machine. This option would ensure that our device wouldn't continue the task until the object is moved from its path. The final option would be to have people always watch the lawnmowers. This option would at first be something of a chore, but you would still relax on the side and not have to be under the sun if you didn't have your device.

TABLE XXI. POSSIBLE OPTIONS FOR ETHICAL DILEMMA

Options	**Description**
1	Install new sensors with the ability to sense objects
2	Kill switch in the presence of an objects
3	App notification of incoming objects
4	Always have supervision on the robotic lawnmower

TABLE XXII. WEIGHT OF ETHICAL SOLUTIONS

Option	Utilitarianism	Egoism	Kantian	Rights	Score
1	1.00	0.00	0.25	1.00	2.25
2	1.00	0.00	0.25	0.75	2
3	1.00	0.00	0.25	0.00	1.25
4	0.50	0.50	0.70	1.00	2.7

By and large, our project's ability to impact our environment positively is something that is one of our group's top priorities. The ability to keep people safe while being able to ensure that our product can fulfill its function is crucial for our business. We were able to learn that when considering our project as well as future projects to keep in mind every possible angle when constructing the device. Ensure that our device is designed so that the right way to use is also the easiest way to use it.

B. Social Impact

In our quest to ask our fellow peers and professors about our idea and their thoughts on our project we were able to gather their opinions on the matter. Although they had their doubts they also began to see our vision when they began asking questions about how it would affect the environment, and what would the sales be like. As a group, we were able to receive mostly positive responses towards the idea of a robotic lawnmower. When we asked professors they asked questions about the design and the longevity of the device. When we asked our peers they would question if it was necessary to have such things because of the current system that is used today. With our questions asked and our peers and professors answered, this would lead to our conclusion on the effect of what a robotic lawn mower would have on local and global culture.

When we asked our fellow peers and professors about the robotic lawnmower it was met with a response of positivity, hopefulness, and doubt, this was common due to a lack of understanding of what a robotic lawnmower's purpose is. For our peers, the confusion was about design and capabilities, and for our professors was as if the market required robotic lawnmowers. How much would they sell for, what would companies improve on, and what would our budget be? It was then that we explained in detail what our plan was and how we would achieve it. If we asked the everyday man about a robotic lawnmower the first thought that came into their mind was

pricing. A common question amongst the group of individuals we asked was current market prices which can be between $600 to $5000 [9]. A regular gas-powered manual push lawn mower can cost around $140 to $567, a significant price difference that shut down the idea of getting a robotic lawnmower for some people [10]. When we explain to them that their purchase is a matter of convenience, we elucidate that the price is higher because of the work you do not have to put in. Our product is something that can become a widely purchased item because of the time we are living in. We live in the age of convenience; it is undeniable that people today are becoming more reliant on technology for everyday tasks. We can see it in many instances throughout history; an example would be lawnmowers. Before the 19th-century people had to cut their grass with grazing animals or sickles and scythes[11]. As new technology comes in it slowly replaces the current solution to the problem, and we believe that the lawnmower is to be replaced by the robotic lawnmower. A report on robotic lawnmowers and their soon-to-be growth in the market shows a growth rate of 12.15% during the years 2022-2027 [12]. This is due to the variety of things such as sports, purchasing a new home, and the improvement of homes are causing higher demand for maintaining lawns. In a local sense, the ability to own a robotic lawnmower is not as out of reach as one might anticipate. With the past pandemic, people have become comfortable inside the house and then out. From FIU students alone 37 out of 50 agreed to the idea of purchasing a robotic lawnmower in the future, seven of them were unsure and six of them flat out did not like the idea. When we asked our professors about the effect of robotic lawnmowers in everyday life, we were met with more hesitation. This was due to the restraints that the current robotic lawnmower has. However most agreed that if the price were to decrease to a marketable level that is acquirable to the average person and restraints of the current machine were attended to it would be able to compete or even surpass the current lawn mowing technology in sales. If we were to look at how robotic lawnmowers would affect the global world it would be a similar aspect to the local one. Specifically, it is predicted to grow in popularity in the North American region and the European region this is again due to the sporting events and residential areas [12].

With this, our design intends to make our robotic lawnmower a product that is both effective and easy to use. The team’s goal is to make the robotic lawnmower able to cut the grass efficiently while being able to handle any problems with the robotic lawnmower itself. The team believes that the effect we have on the customers and the market is an adequate addition to the lawn mowing services. Customers that use our product will be able to effectively cut grass without having to be outside to commence this process. People that have lawn mowing companies will be able to purchase our product to use in their service. While it does take away the aspect of physically cutting grass it does not replace jobs, it only improves the experience. The value that our team judges is based on multiple companies that use robotic lawnmowers or people that have purchased robotic lawnmowers. These companies take our code of ethics very seriously and were used as examples when constructing and debating our code of ethics. These companies such as Bosch, Friendly Robotics, Global Garden Products, and Husqvarna group were all considered when reviewing the effects and values we would have when constructing our project [13]. Lastly, the vision of the ‘Good Life’ is what our project aims to produce. A brief explanation of the ‘Good Life’ is an ideology that makes life easier for mankind. The team's strongest running idea when contemplating the robotic lawnmower is the idea of making life easier. In all of our experiences,

we had all had to mow the lawn. It has become a chore that is engraved into American culture. The dream of most Americans is to be able to call a place their own, this is true for the members of this team. Americans want to have this home as a safe place to come to when they have a long day at work, so why not have a beautiful front yard as well?

As a result, the impact that robotic lawn mowers have on the community is something that is to be determined in the future. Currently, it is debated by many to be the future because of its ability to self-automate and perform tasks without the user being present. A robotic lawnmower can impact our local culture because society depends on technology and the convenience that it brings. This occurrence of having technology do the jobs of humans is becoming more and more culturally accepted with more machines replacing or aiding in the work process of mankind. So I can confidently say that with the research and surveys that the robotic lawnmower is something that will become more and more popular throughout the globe.

XVII. Concept Development

The purpose of this section is to look at and examine multiple possible solutions for our product and determine the best option. It is not always best to go with the very first solution drafted; rather, it's best to lay out all possible approaches to a problem and go through each possible solution. It's important to remember that there will always be trade-offs as some combinations of solutions don't do well with each other since certain solutions take more priority, have a higher weight than others, or are impractical to implement. To take away from this, it's challenging to find a combination of solutions where everything works together extremely well with no compromises; the main purpose of this section is to find the best combination that would be most feasible to implement and provide the best results. This is a multi-step process; first, there's the concept fan, which allows looking at the ideas from a broader point of view. After that, the combination table is next; there will be multiple combination tables pairing up various possible features or components. Lastly is the concept selection, in which the weight of all the different combinational tables is calculated, which will then give the best solution for the product.

A. Concept Fan

There would be four main factors to consider when designing the robotic lawn mower, and this is where the concept fan will represent the possible components that could satisfy the objectives when developing the lawn mower. Wireless communication is very important for the functionality of the product and to satisfy some of the objectives; therefore, Bluetooth and WIFI are possible implementations. The physical blade is an integral part of the product; some options to go with are weed eater string and a generic lawn mower blade; these will determine grass-cut quality, power consumption, and other client needs. The very brain of the product is the controlling unit; some possible options are Raspberry pi Zero, Arduino UNO, and Particle board. It's important to choose the right one as it determines power consumption and possible options for functionalities such as sensors involving safety and navigation. The last part to consider is the actual build material; the main objective here to satisfy is durability and weatherproof which is why the filament chosen to print and build the body is PP GF30, polypropylene-based filament filled with 30% glass fibers for Fused Filament Fabrication.

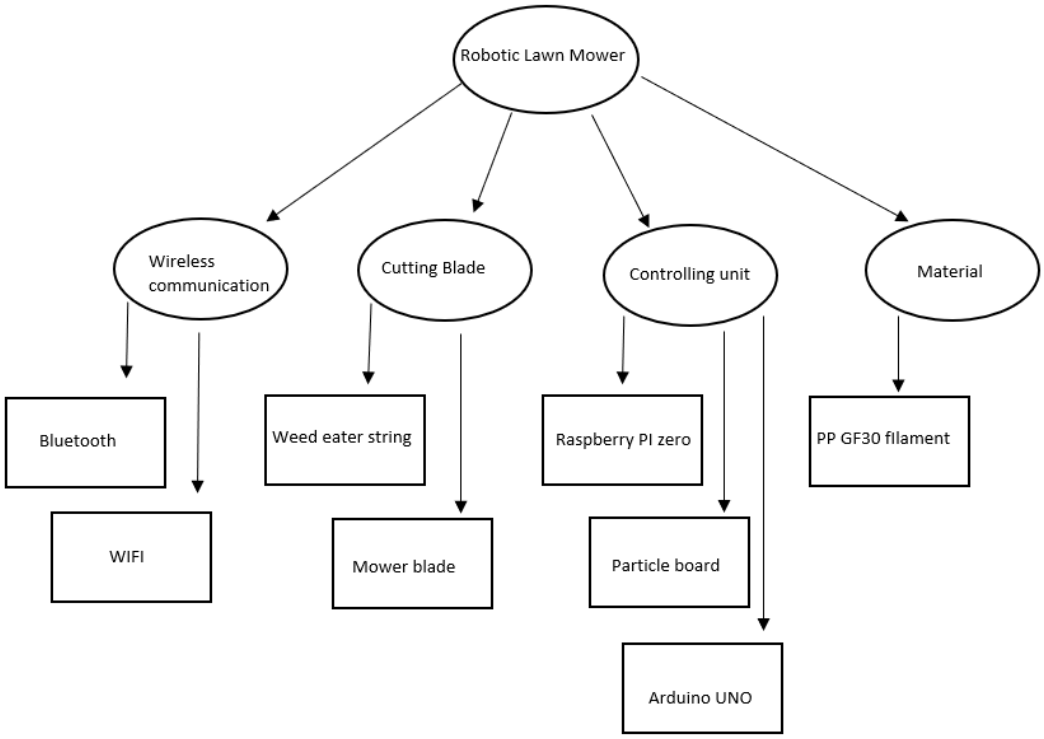


Fig. 12. Concept Fan

B. Alternative Options

Option 1: **Bluetooth, Weed eater String, Arduino UNO**

In Fig. 13, this first concept design option involves using Bluetooth for wireless communication with the user. The Robotic Lawn Mower would also be using a weed eater string to gut grass since its less power consuming to use and more easily available on market which allows easy replacement. As for our controlling unit, an Arduino Uno will be used.

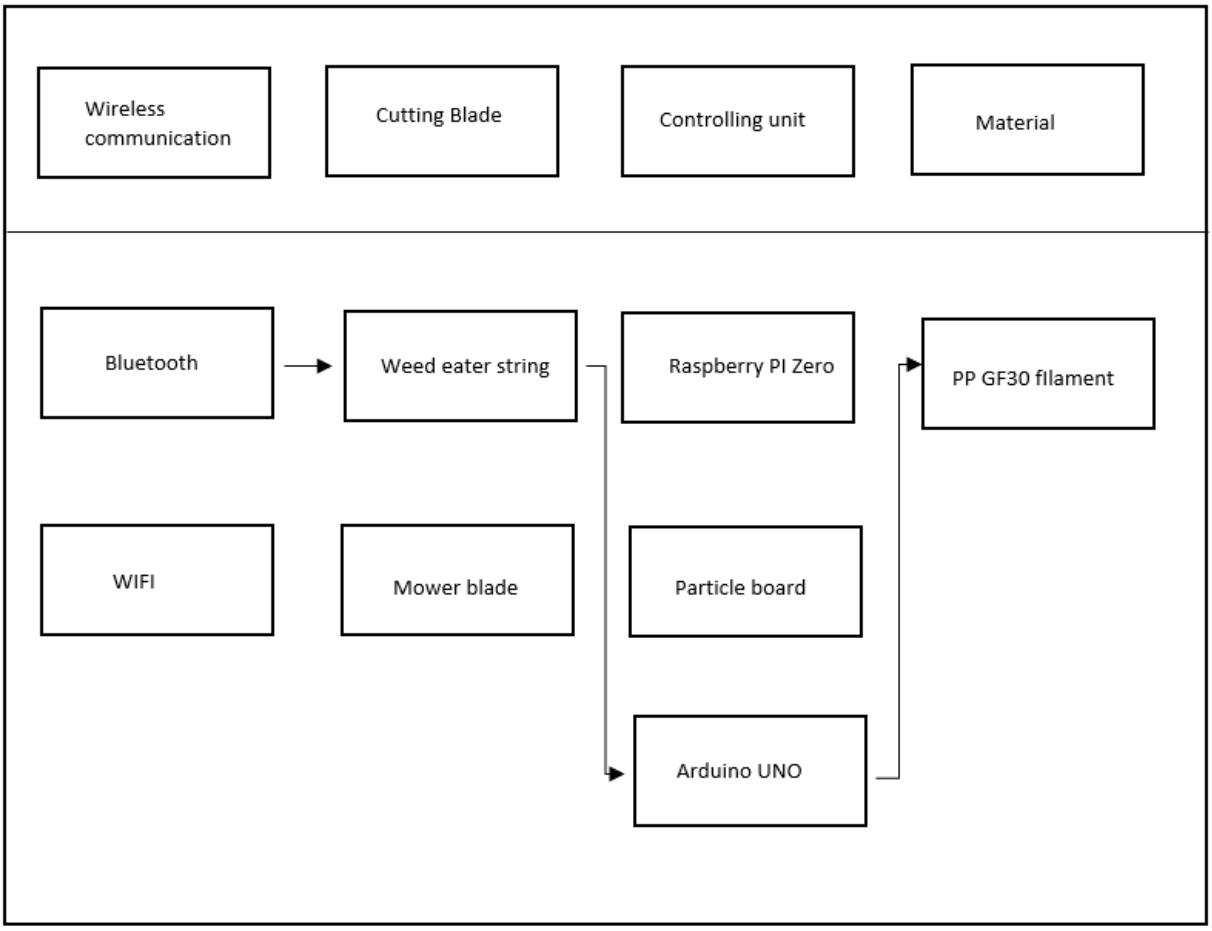


Fig. 13. Option 1

Analyzing each component and weighing the advantages and disadvantages, here is what was concluded below:

1) Advantages:

- Stable connection as long as the user is within range
- Weed eater string is less power-consuming and easily replaceable than a mower blade
- Programmed with C which is faster and easier to connect sensors with and the board is less power consuming
- Overall least power-consuming combination
- Components are cheaper

2) Disadvantages:

- Arduino lacks certain capabilities and lacks the computing power
- User won't be connected over longer distances
- Weed eater strings will need to be replaced more frequently and sometimes in the middle of a cut
- Weed eater is also inconsistent with cut quality, it cuts by whacking the grass off

Option 2: Wi-Fi, Mower Blade, Raspberry PI zero

In Fig. 14, this concept design option involves using WIFI for wireless communication with the user. The Robotic Lawn Mower would be using a generic lawn mowing blade that's available in most hardware stores. As for our controlling unit, a Raspberry Pi zero will be used.

- Raspberry pi zero has more computing power and possible options to add various sensors and peripherals; Also opens future opportunities for additional new features and addons

- Raspberry pi zero has more computing power and possible options to add various sensors and peripherals; Also opens future opportunities for additional new features and addons

- Most powerful system over all other combinations and better reliability Below is the conclusion for the advantages and disadvantages of this possible combination of components in the robotic lawn mower

1) Advantages:

- Stable connection over longer ranges
- Lawn mower blade does consistent and clean cuts
- Less frequent replacement of the blade

- Raspberry pi zero has more computing power and possible options to add various sensors and peripherals; Also opens future opportunities for additional new features and addons
- Most powerful system over all other combinations and better reliability

2) Disadvantages:

- Higher power consumption due to Wi-Fi, mower blade and raspberry Pi zero
- Components more expensive
- Stable Wi-Fi connection required
- Mower blades would be slightly more difficult to change

Option 3: Wi-Fi, Mower Blade, particle board

In Fig. 15, this Last concept design option involves using WIFI again for wireless communication with the user. The Mower blade would also be used again for our blade option. This time for the control unit, a particle board would be used.

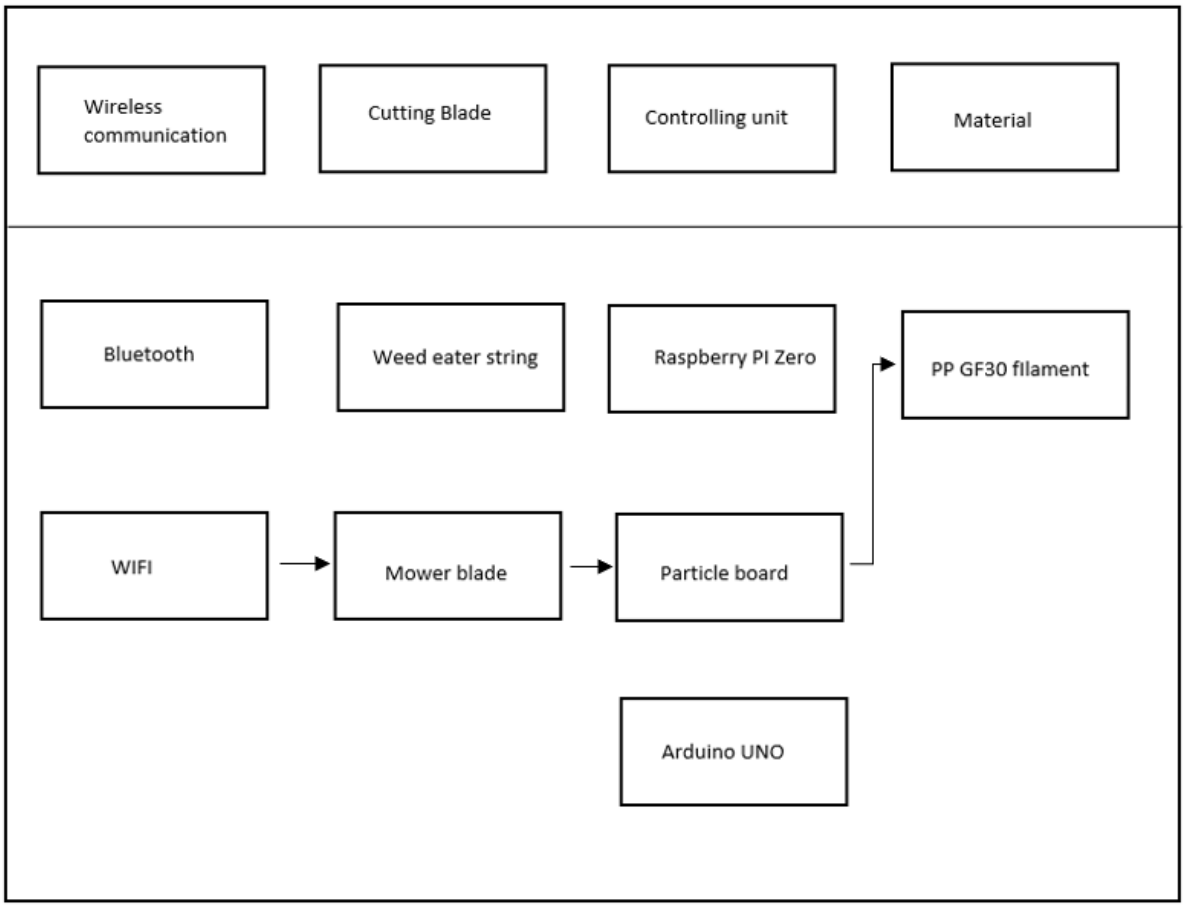


Fig. 15. Option 3

Below is the conclusion of advantages and disadvantages for the last possible combination of components for the robotic lawn mower:

1) Advantages:

- Stable connection over longer ranges
- Mower blades are more reliable and requires less frequent changes
- Particle board uses C programming and has a large library along with wider IOT application making implementation simpler
- Moderate power consumption of overall system compared to other options

2) Disadvantages:

- Particle board is expansive than an Arduino

- Stable Wi-Fi connection required
- Mower blades may be harder to replace for some people

C. Concept Selection

The next part in concept development is concept selection, this is where the numerical weight of each component is calculated, and the overall value of each option is determined. First, the importance of each object is determined relative to the other. A scale is assigned where one is equal importance, three is moderately more important, five indicates strongly more importance, seven indicates very strong importance, and nine is extreme importance. The G-mean is also then determined from these given values; the G-mean will give us the relative importance of the objective.

Scale of importance: 1 = equal, 3 = moderate, 5 = strong, 7 = very strong, 9 = extreme

TABLE XXIII . OBJECTIVE WEIGHT TABLE

Objectives	Assembly	User Friendly	Safety	Marketability
Assembly	1	1	1/3	5
User Friendly	1	1	1/3	3
Safety	3	3	1	5
Marketability	1/5	1/3	1/5	1

Table XXIV. CONCEPT SELECTION IMPORTANCE SCORE

Objectives	Assembly	User Friendly	Safety	Marketability	G-Mean	Weights
Assembly	1	1	0.33	5	1.13	0.22
User Friendly	1	1	0.33	3	1.13	0.22
Safety	3	3	1	5	2.59	0.50
Marketability	0.20	0.33	0.20	1	0.34	0.07
				Total	5.19	

Table XXV. CONCEPT SELECTION WEIGHT CALCULATIONS

$$G.\,Mean = (A \quad \times A \quad \times \ldots \times A\,)\_$$

$$w = \frac{G.\,Mean}{Total}$$

Table XXVI. CONCEPT SELECTION TOTAL SCORE

Constraints		Option 1		Option 2		Option 3	
40min battery Life		YES		YES		YES	
Good connectivity		NO		YES		YES	
Inexpensive		YES		YES		YES	
Durability		NO		YES		YES	
Sensory Awareness		YES		YES		YES	
Objectives	Weight						
Assembly	0.22	4	0.88	4	0.88	4	0.88
User Friendly	0.22	2	0.44	4	0.88	4	0.88
Safety	0.50	5	2.50	5	2.50	5	2.50
Marketability	0.07	3	0.21	5	0.35	4	0.28
Total Score			4.03		4.61		4.54

The final part is computing the total scores and considering the constraints of the projects. In the final selection process, each option is relatively ranked to the objectives from a scale of one to five and then multiplied by the weight of the objective calculated in the previous steps. Options that do not satisfy any constraints are automatically discarded. The final choice that will be implemented is the option that has the highest total score.

From a careful analysis of all the options and data available, it has been finally concluded that option two will be implemented as it's deemed to be the best possible choice. Option two and option three were a close match and had a total weight difference of 0.07. In the end, both fulfilled all the objectives almost to the fullest as both would be systems with good safety features, easy maintenance, and user-friendly app features, and were durable enough to stand outdoor conditions. The reason option three lost was that it lacked in the marketability section; option two had a powerful controlling unit that was able to compute data faster and with the availability of implementing more features of data collection compared to option three. Option one was already qout as an option due to not satisfying good connectivity constraints, but even excluding that, it still scored much lower. It lacked in the marketability section due to its less powerful controlling

unit compared to other options. It also lacked in the user-friendly section, as the weed eater option would require constant user intervention to fix jammed strings or overall replacement. To conclude again, after weighing all the options, option two came to be the most feasible to implement as it satisfies all the objectives and constrains of this project.

XVIII. END PRODUCT DESCRIPTION AND OTHER DELIVERABLES

This section of the paper is crucial as it relates to the project itself and deliverables in the future. In this section, through complex diagrams, the relations, input, and outputs of the project will be displayed to give a general understanding of the driving components of the robot. With the diagrams and tables laid out, readers will also get an understanding of the design of the product and a clear understanding of its functionality once the product development is finished.

A. End Product Description

The end product description will display and explain the functionality of the product and the components that make it up. It will go into detail and describe each part of the product. This is essential for the designers to materialize the product and gain a more general understanding of the product. It also helps the designer to look at the overall product from a different perspective and helps with troubleshooting and adding potential changes while understanding how it will affect the overall product. Users will also find this section useful as they would also like to know the complexities and design of the product.

The parts that go into driving the overall lawn mower will be explained in the following section. The robotic lawn mower will be explained from three different levels, from the top displaying a more general description to the bottom level that shows detailed block diagrams and inner connections. The overall product will take in sensor data and with that, the main brain, which is a microcomputer, will carry out tasks to get the mower functional. The following Fig. 16 shows a level 0 view of the robotic lawn mower. There are a few inputs, sensor data such as obstacle sensors, navigation data, and data received from the user app. There's also power input to provide power to the overall product. With the processing of all the inputs, the mower will output data to the user app and signal to control the blade and wheel motors.

Fig. 16 Level 0 Robotic Lawn Mower Diagram

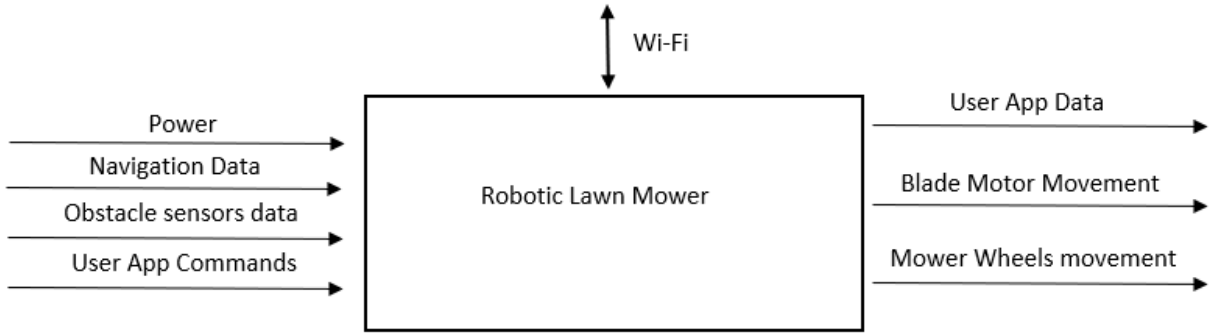


TABLE XXVII shows the level 0 functionality of the robotic lawn mower. It is organized in a way to help readers understand the inputs, outputs, and functionalities in a simple

straightforward way. The overall product will take in the inputs and translate the data so the mower will function to cut users' lawns with almost no user intervention.

TABLE XXVII. Level 0 Robotic lawn mower Table

Module	Robotic Lawn Mower
Input	D. 120V 50-60Hz AC E. Navigation data of lawn F. Obstacle sensor data from any objects on the mower path G. Mower commands sent through the app H. Wi-Fi signal
Output	A. Data sent and displayed on the app on mower work progress B. Signal sent from the motor controller to control the cutting blade C. Signal sent from the motor controller to control wheel speed and movement D. Wi-Fi signal
Functionality	I. To cut the user's grass based on the data received from App and various sensors and keep the user updated on progress

Fig. 17 shows the level 1 diagram of the robotic lawn mower. It will give the user and the designer a more detailed view of the previous black box diagram, where the inner parts of the mower is also explored. It will show to which component the inputs will specifically go and from where the outputs come out. First, there will be power provided to the power supply which will be a Li-ion battery which then provides DC power to all other parts. There's also ultra-sonic sensor which will take in obstacle sensor data to process and send it to the Arduino UNO controlling unit. The Arduino UNO is the main controlling unit and it will take in power, sensor data, commands from the user app, and connect to WIFI to process everything. After processing is done, the data is sent to the user app and signal to the motor controlling unit. The motor controller will take in the signals from the controlling unit to send out PWM signals to control the blade and wheel motors.

Fig 17. Level 1 Robotic Lawn Mower Diagram

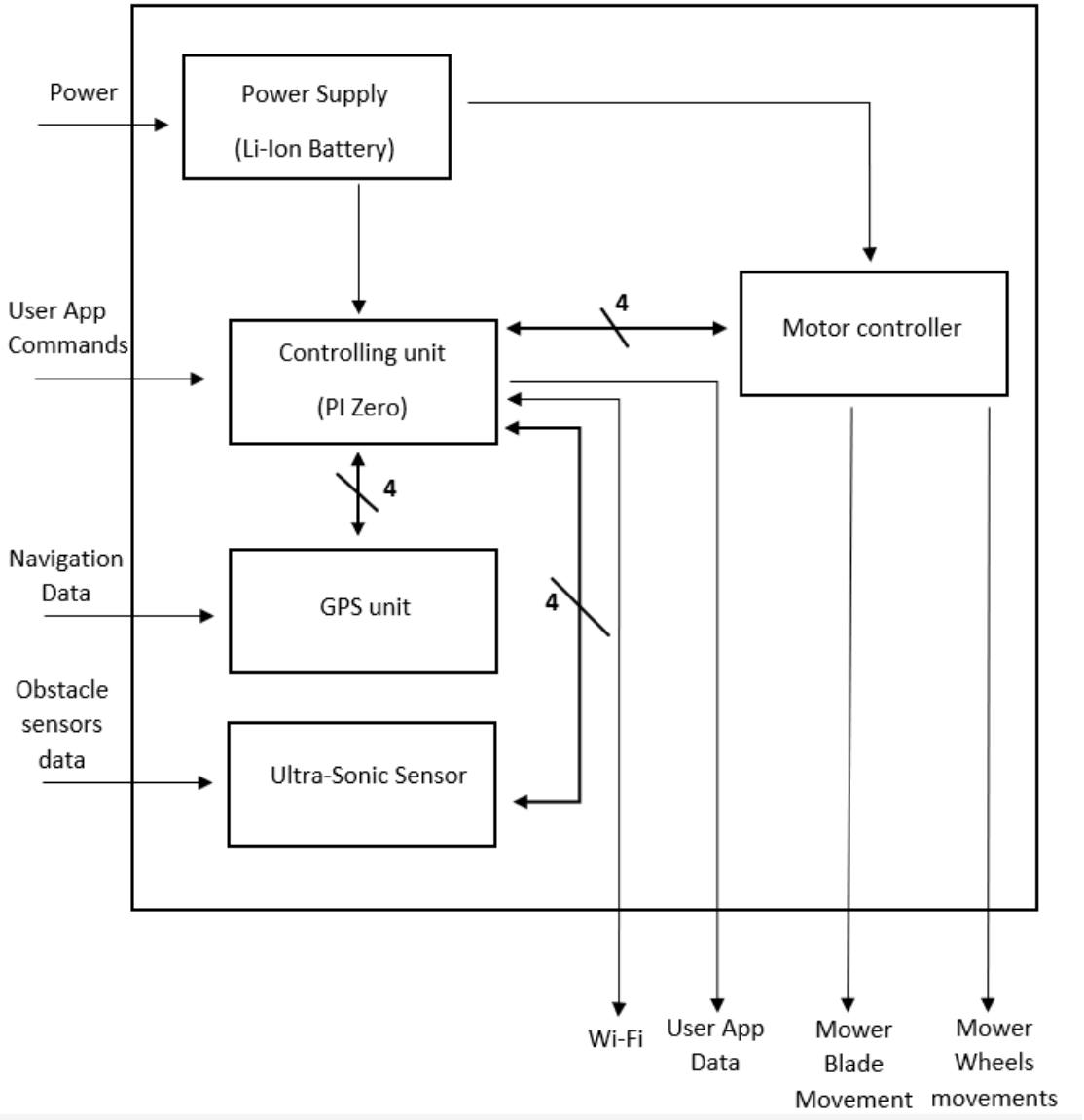


TABLE XXVIII shows the level 1 functionality of the robotic lawnmower in a more detailed manner compared to the previous table. It's organized in columns that will show the individual components and rows explaining the inputs, outputs, and overall functionality. There are five different components that make up the inners of the robot, they have their own inputs and outputs to other components or outside of the robot.

TABLE XXVIII. Level 1 Robotic lawn mower Table

Module	Motor Controller	Power Supply	Controlling Unit	Ultra-Sonic Sensor
Input	12v input from Li-Ion battery supply The motor speed control signal from Arduino UNO	120V 50-60Hz Ac input	Data from obstacle sensor Data from motor controller DC power App commands WIFI signal	Signals received based on weather something is on the path of the robot or not
Output	Mower cutting blade speed signal Mower wheel's speed signal	12v DC power for motors and 5v DC power for sensors and microcontroller	Obstacle sensor trigger Motor controller signal WIFI signal Data to user App	signal back to microcontroller telling weather obstacle is in front or not

Functionality	To Control the blade's speed such as on and off. Also controlling mower wheels to navigate lawn	To take in AC voltage and output appropriate DC voltages to power the mower	Main brain of the robot controls all functionality of sensors and motors. Handles data and sends to app	Tells controlling unit if there is an obstacle so it can decide on the action to take

B. Functions

This section will explore the specific functionalities of the components and their own block diagrams. It will go into their own operations and their own subsystems the shows how these specific components operate. After this section, it will give a better understanding of why these components are used and how they will be placed in the robot.

Fig. 18 shows a level 2 diagram and inner composition of the power supply. There is an input of 120v 50-60Hz AC to the component. The inner circuitry is responsible for converting the AC voltage into the appropriate DC voltage and charging the LI-ion battery. The battery in turn will provide the proper 12V to the motor controller and through a step down LM2596, it will provide 5V for the main controlling board.

Fig 18. Level 2 Power Supply Diagram

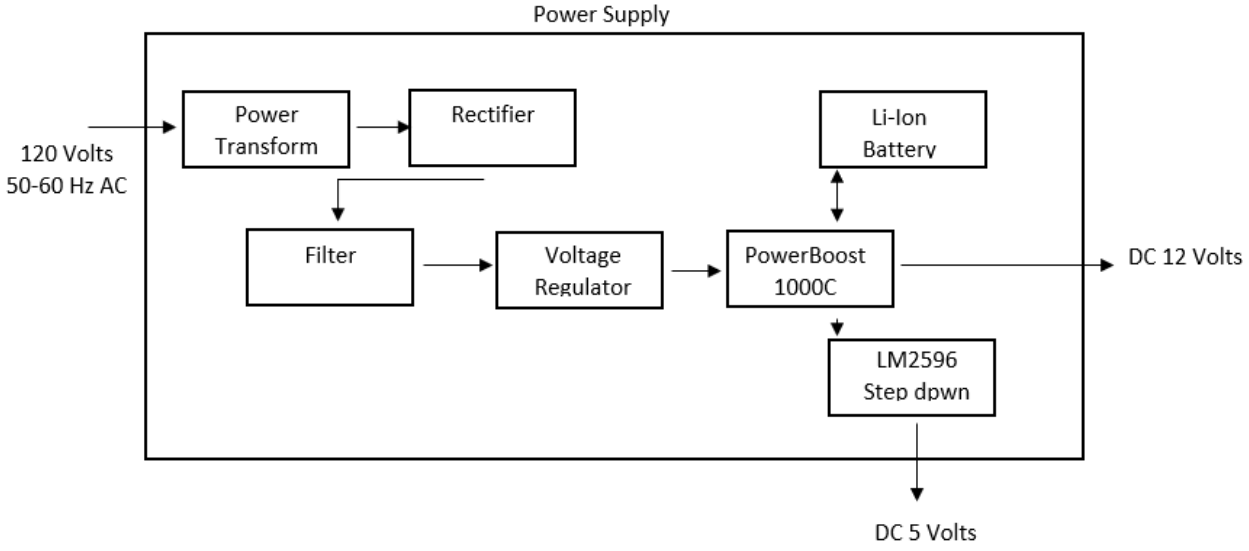


TABLE XXIX will show the level 2 functionality of the power supply. It will get 120V 50-60Hz AZ and transform that to DC to charge the battery, the battery is then responsible for providing the DC voltage to all other components.

TABLE XXIX. Level 2 Power Supply Table

Module	Power Supply
Input	II. 120V 50-60Hz AC
Output	III. 12V DC and 5V DC
Functionality	A. To take in power directly from a wall and transforming that to DC voltage appropriate to power the Li-Ion battery which will provide the power for the DC motors, sensors, and microcontroller itself.

TABLE XXX shows the functionality of the Arduino UNO. It shows the various inputs and outputs to other components. These will determine how the lawn mower functions of carrying out tasks.

TABLE XXX. Level 2 Arduino UNO Table

Module	Arduino UNO
Input	A. Data from obstacle sensor B. Data from motor controller C. DC power D. App commands E. WIFI signal
Output	A. User Inputted map instructions B. Obstacle sensor trigger C. Motor controller signal D. WIFI signal E. Data to user App

Functionality	IV.	Main brains of the robot. Will take in sensor data, power, and control of motors through the pin headers. Will use the GPIO, I2C, PWM and UART for data communication between other components. The processor capable of reading the sensor data and handling instructions for mower functionality. WIFI chip will handle wireless communication which will allow mower to communicate through app.

Fig 20 shows the level 2 diagram of the motor controller. A L298 Dual H bridge module will be used for the control of the motors. It will take 12V to power up and an A and B input to enable functionality of the two motors. The logic value will determine the PWM signal the module will send out to control the speed of both motors.

Fig 20. Level 2 Motor Controller Diagram

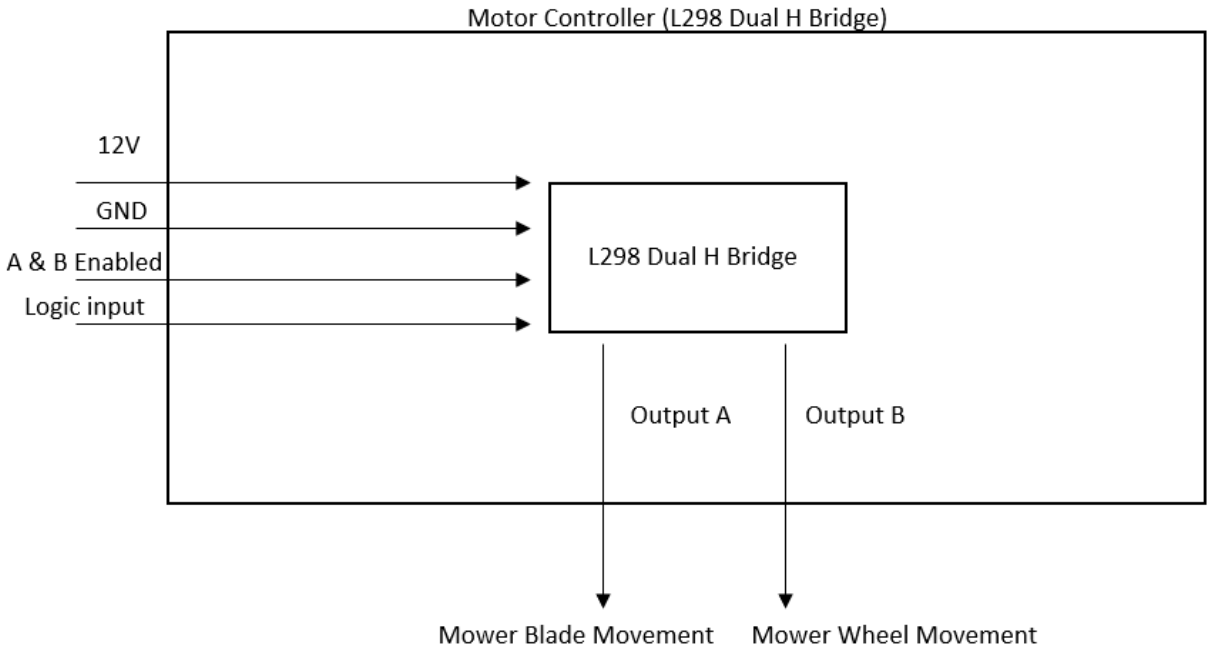


TABLE XXXI shows the functionality of the L298 H bridge motor controller. It displays the required inputs and outputs to control the motors on the robotic lawn mower.

TABLE XXXI. Level 2 Motor Controller Table

Module	L298 Dual H Bridge Motor Controller

Input	I. 12V J. GND K. A & B Enable L. Logic input
Output	E. Output A (Mower Blade) F. Output B (Mower Wheel)
Functionality	V. Controller is connected to 12V power and GND from power supply. Through the A and B enable from controlling unit, both motor controls are enabled. The input logic values from the controlling unit determine the speed of the wheel and blade motors.

Fig 21 is the level 2 diagram of the obstacle sensor. It uses a HC-SR04 ultrasonic sensor module which is powered from 5V DC and will take in a digital signal from a microcontroller to trigger the echo on the module. The sensor will listen back to the echo and send the signal back to the microcontroller.

Fig 21. Level 2 Obstacle Sensor Diagram

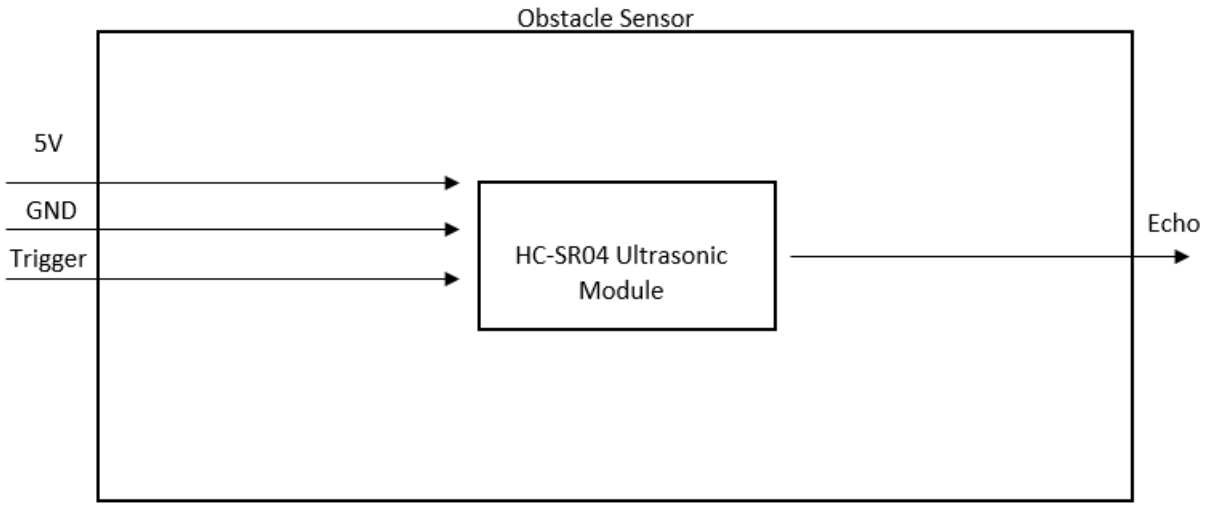


TABLE XXXII displays the functionalities of the HC-SR04. It displays the inputs required and output data for the controlling unit to process.

TABLE XXXII. Level 2 Obstacle Sensor Table

Module	HC-SR04 Ultrasonic Module
Input	M. 5v DC N. GND O. Trigger
Output	G. Echo
Functionality	VI. The Arduino UNO will provide ground and power to the sensor along with a digital signal to trigger the sensor to send out ultrasonic signal. The module will take in the reflected signal back and send it back to Arduino UNO through Echo output. The Arduino UNO will determine obstacle and distance based on the time it took to get reflected signal back

Fig 22 shows the level 2 view of the GPSs module. It will be using a GT-U7 GPS module which takes 5V to operate and receive serial data from the microcontroller. The module gets GPS data from the antenna and will transmit the information through a serial connection back to the main controlling unit.

Fig 22. Level 2 GPS Module Diagram

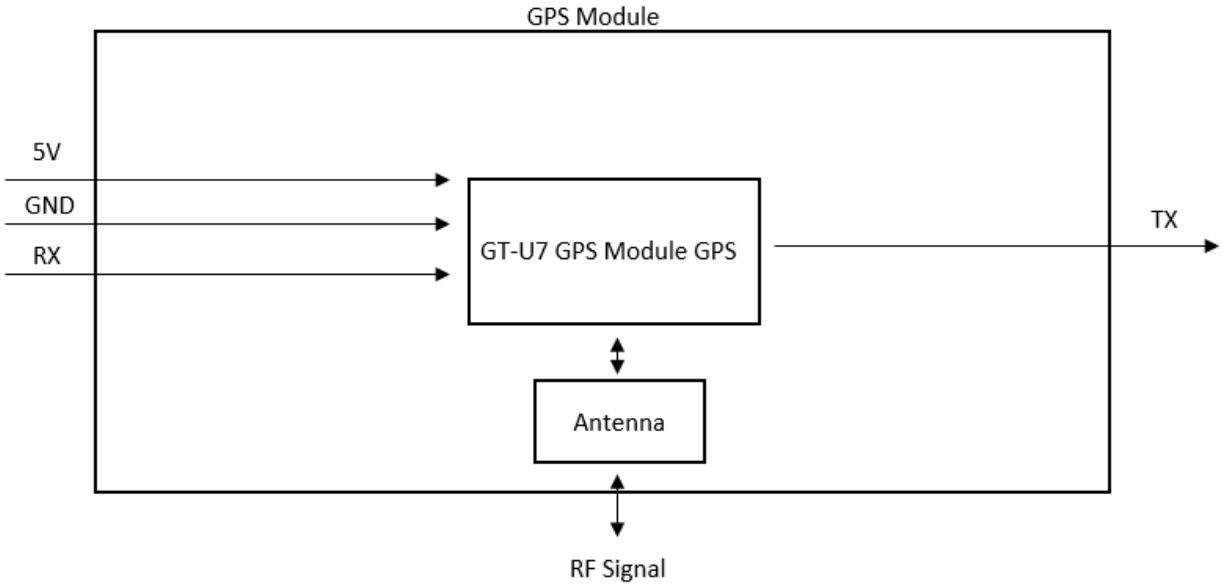
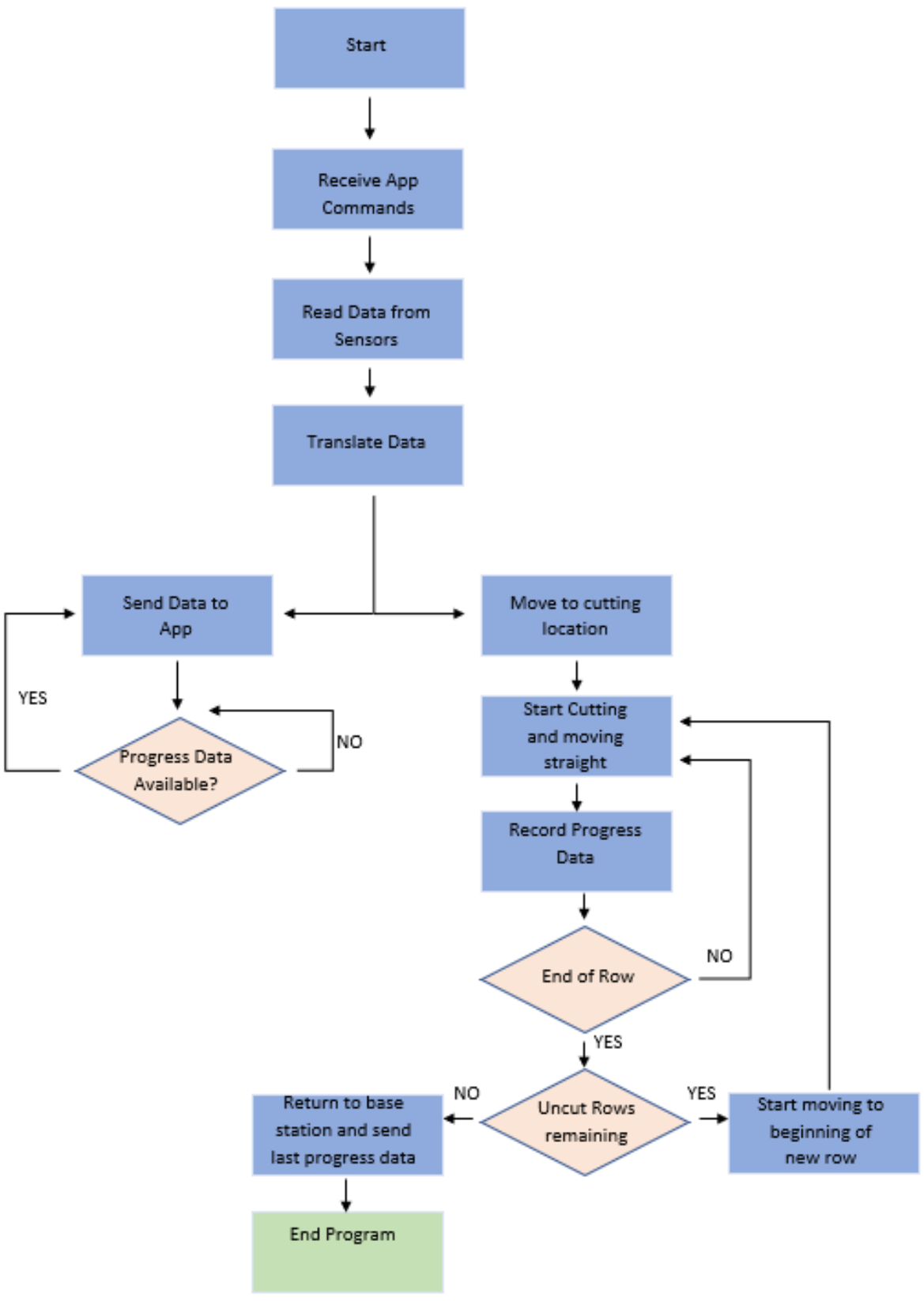


TABLE XXXIII shows the functionality of the GT-U7 GPS Module. In a categorical manner it shows the inputs, outputs, and the functionality of the module.

Fig 23 shows a simplified flow chart of the programs that are going to be running on the Arduino UNO. Since the robot is essentially an embedded system, this part is necessary for users and designers to visualize how the processing of tasks will take place. The flow chart explains how the robot initializes first with sensor data and app commands. With the initial setup, it will fork out into separate tasks. It will continuously send out work progress data while the mower is running and in parallel, it will set up to cut the grass by sending commands for the mower to travel to the work location. Once at the location, the mower will cut the grass in a straight line until the end of the row, it then switches to the next row until there are no rows left to cut. I will continuously update work progress data in between. Once no rows remain, the program starts the task of returning the mower back to its base station to complete the program and end the job.

Fig 23. Program Flow Chart


Start
Receive App Commands
Read Data from Sensors
Translate Data
Send Data to App
Move to cutting location
YES
Progress Data Available?
NO
Start Cutting and moving straight
Record Progress Data
End of Row
NO
YES
Uncut Rows remaining
NO
YES
Return to base station and send last progress data
Start moving to beginning of new row
End Program

C. Specifications

TABLE XXXIV will show the specifications of each component of the robotic lawn mower. It will list out the requirements for operation, details about running requirements such as voltage, and physical specifications such as size and weight. This is useful for the designer to keep in mind during the designing process, it lists out by what specifications to design the robotic lawn mower around and certain limitations the design will have.

TABLE XXXIV. Specifications Table

	Components
Li-Ion Power	VII. Rechargeable VIII. 12v output IX. 5000mAh X. 1A max recommended charge rate XI. 50x29x72mm and 9.6 ounces XII. 2A mac continuous current discharge XIII. 2.4 hours rapid charging
L298 Dual H Bridge Motor Controller	XIV. 43 * 43 * 27 mm and 6.6 ounces XV. Logic voltage at 5v XVI. Driving voltage from 5v - 35v XVII. 25w max power VIII. Storage temperature from - 20 °C to + 135 °C
HC-SR04 Ultrasonic Module	XIX. 2cm – 400cm range of measurement XX. Range accuracy up to 3mm XXI. Includes ultrasonic transmitter, receiver, and control circuit XXII. 0.81 ounces and 4.25 x 3.4 x 0.9 inches

D. Other Deliverables

This overall report will provide a broad range of information that's essential for the reader to understand to gain a total understanding of the robot and the process that went into its design. Even with all this information, it's not expected for readers to read through all of it and gain a total understanding of the product. Certain aspects of the paper are beyond the reader's understanding and may not pertain to their interest. It is why this section aims to list deliverables in the future

that will fill in the lack of understanding of the product for the users. The deliverables will be used as a guide for the lawn mower other than this report.

- User Manual:

  A manual for the lawn mower will be created by the team. Its aim is to provide a simplified and quick guide on how to set up and use the lawn mower.

- Video Presentation:

  The video will show the robotic lawn mower in action. It aims to motivate viewers to use the product along with providing a visual guide to the functionalities and setting up of the product. It will show the standard procedures to follow for the set-up and use of the product.

  Some changes to the product were made throughout the project. One main change was not implementing GPS functions. This will hinder smart mapping where the mower will determine the best path to mow and saving where it last mowed. This was a decision made upon the team due to the inaccuracies of the GPS module.

In conclusion, this section's goal was to visualize and explain the in and out of the overall lawn mower and its functionalities. The end product description is a more general summary of the components, inputs and outputs of the product and their functionalities. The functions provide a much more detailed overview of the individual components. It shows their inputs and outputs in much detail along with their functionalities in the overall product, inner circuitry, and program flow. The specifications summarize certain quantitative aspects of the component for the designers to abide by. The last section, deliverables, summarizes what additional information will be provided for the users in the future in order to give a better understanding of the product other than this report.

XIX. PLAN OF ACTION

As with any project, time is of the essence to meet customer needs and satisfaction. A plan of action will help keep the team on track, engaged, and focused on completing tasks to meet the end product description. Creating a plan of action will draft out critical milestones of the project design and responsibilities. It will also provide a breakdown of the work performed by each member. The team will create a plan of action and utilize charts for determining deadlines and to ensure tasks are completed before the deadline.

A. Statement of Work

A. *Scope*

Senior Design Team 16 will be working on constructing an Autonomous Lawn Mower. The lawn mower will be located outdoors for charging and mowing. With app control, the user will be able to start the mower within the app so it will require minimal handling for operation. The mower will have Bluetooth and Wi-Fi connectivity for wireless control to start, stop, and for notifications within the application. Notifications will include things such as the mower is cutting the grass, completed a task, or if an error like an obstruction is presented.

B. *Location*

All work regarding the assembly of the Autonomous Lawn Mower will take place at Jason's workshop. This location will be the teams in-person meeting location for all physical work being done to the device. Any software coding or other computer related tasks will happen remotely. Although most of the coding will be assembled beforehand for uploading to the mower. A communications platform like Zoom will be utilized so the team can continue to work together remotely. Any other minor tasks will be done individually based on individual team member's schedule and the complexity of the task.

C. *Period*

The project period started in August 2022 and the final product will be completed in March 2022, which is the end of the project period. The design, assembly, and all fundraising strategies of the Autonomous Lawn Mower will be completed during this timeframe. The Autonomous Lawn Mower will be fully assembled in April 2023 and any other fixes will occur after that date.

D. *Responsibilities*

The individual members of the group will have clear-cut roles and responsibilities assigned to carry out. Every member of Senior Design Team 16 has experience with either electrical or computer engineering. Team member assigned roles are as follows:

Jason: Team Leader – Responsible for scheduling arrangements with the workshop where all physical work will be done. He will also assist in creating the structure and assembling the final product.

Miguel: App Developer– Responsible for scheduling meetings and ensuring tasks are completed within a timely manner. He will also be the lead on constructing the mobile application for the mower. This will be the primary user interface for the consumer.

Blake: Hardware and Software Designer – Responsible for selecting correct parts and materials for the device. He will be reaching out for any additional sponsors for any additional parts needed. He will be the lead in troubleshooting any potential issues in the hardware and software design. He is also creating the 3D print for the mower

Muda: Hardware and Software Designer – Responsible for creating the structure and assembly of the final product. He is also responsible for the software development for the navigation of the device.

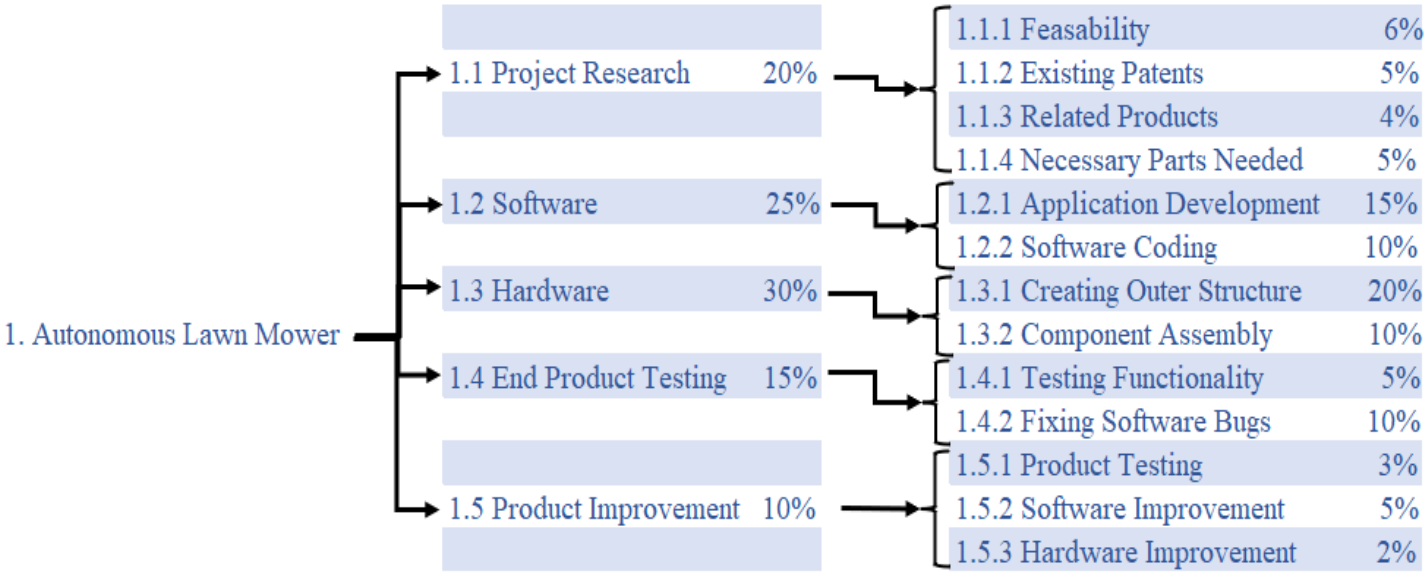
Fread: Software Designer – Responsible for the software of all interconnected devices. He will also assist in troubleshooting any software issues when building the final product.

B. Work Breakdown Structure

The Work Breakdown Structure is all project phases, tasks, and milestones presented in a hierarchical list. The WBS will follow the 100% rule as all necessary parts of it will cover all sections for completion of the project. The percentages will compare each sections relative time and complexity for a visual as to how much time is spent in each. Subtasks related to each phase are also displayed in the WBS. This will allow the team to be time efficient with all tasks going forward. The Work Breakdown Structure for the Autonomous Lawn Mower design is shown in Fig.1.

A. *Phase 1: Project Research*

- Objective: Finding any existing patents, related products and designs, determining the necessary parts, and determining feasibility to be aware if the project can be done easily.
- Approach: The team will research existing patents to determine what can be done and what cannot be done based on the existing patents. Researching related designs to see how others has approached a similar type of project. The team will review feasibility to acquire whether the project is approachable. With all information collected, determine what parts will best fit our design.
- Expected Results: Researching patents so the team does not infringe on any other ideas while following all government policies and laws, whether the project is indeed



approachable, and having all necessary hardware parts for future assembly and operation.

Fig. 1. Work Breakdown Structure (WBS)

B. *Phase 2: Software*

A. Objective: Design a mobile application for notifications and controlling the device and develop software code for operation of the device itself and all interconnected devices.

B. Approach: The team will develop an application for mobile devices using a React Native. This will ensure compatibility between all consumers depending upon what mobile device operating system the user currently owns. All designated team members who will be

designing the software code will develop a program that best suits the devices operation requirements and compatibility for all interconnected devices.

C. Expected Results: The mobile application will be completed and fully operational. It will work smoothly within the designated operating system and will communicate well with the device based on Bluetooth and/or Wi-Fi technology. The program code will be fully operational with no errors when compiling before uploading to the device. The team will attempt to have few operational errors due to the code to prevent excessive modifications to the code during the product improvement phase.

C. *Phase 3: Hardware*

A. Objective: Creation of the outer body, waterproofing the outer structure, and assembly of sensors and motors.

B. Approach: The team will utilize a 3D modeling software to design the outer body and any supporting members needed to hold all interconnected devices such as motors, sensors, and wheels. A 3D printer will be employed in creating all outer body structures, supporting members and wheels for constructing the device. Assembly of all interconnected devices will happen, and code will be uploaded to the controller for operation.

C. Expected Results: The device will be fully assembled and operable to meet all specifications of the hardware and software requirements

D. *Phase 4: End Product Testing*

A. Objective: Testing to determine if the device has reached the end product description based on design and operation.

B. Approach: The team will test the devices operation based on different situations related to lawn mowing such as the mower approaching and detecting obstacles, how the device reacts to obstacles, maneuverability on different types of terrain, cut quality of the lawn, and testing the mobile application for communications like notifications, starting the mower, stopping the mower, and ease of use for the consumer. Any minimal software bugs hindering operation will be corrected in this phase

C. Expected Results: The product will operate as expected based on product description with minimal alterations to the software code. The device will react to obstacles as required, handle all terrains as expected, provide a quality cut lawn, and the mobile application will work seamlessly between the mower and mobile device. The application will also be easy to use for the consumer.

E. *Phase 5: Product Improvement*

A. Objective: Fixing any software bugs and hardware as needed to allow for a better operating autonomous lawn mower.

B. Approach: The team will continue to test and take note of any flaws related to the operation of the mower. This will help uncover any bugs that are software related and alterations to the hardware as needed.

C. Expected Results: A completely autonomous lawn mower that will operate with ease and with no complexity to the user.

C. Project Milestone

Milestones are created to make certain that the project is on schedule, this will also ensure that specified goals are met within a specified time. It will help the team stay on track to meet all deadlines for the project. Project progress can be expressed with milestones and shows what parts of the project will be implemented. The Autonomous Lawn Mower Design project has six milestones:

A. Research Phase – 9/20/2022
B. Software Design and Application Development – 11/10/2022
C. Hardware Design – 1/5/2023
D. End Product Testing – 3/31/2023
E. Product Improvement – 4/1/2023
F. Final Product Design – 04/17/2023

The research phase will consist of research background information. This includes feasibility analysis, researching existing designs, and current patents. Utilizing a time period of about a month will allow for plenty of time to determine if the project is doable and verifying that the team is not infringing upon current patents. The time will also be used to determine the necessary materials needed to create the design after every other part of the research phase is complete. The software design and application development phase lasts for about a little over a month. This allotted time is for creating the mobile application and software code for the device. The team has determined that this time period is indeed needed so that there is enough time to create all the code while fixing any bugs before product implementation. Spending more time here now will help dramatically decrease the time spent in product improvement. The hardware design phase is where the team will create and assemble the device. Not much time is needed here compared to the software design and application phase. The product will be printed, and all components will be installed to the body of the mower during this phase. The product improvement phase will give the team enough time to work out any issues with the hardware design. Also, any other bugs in the software will be corrected at this time.

The final product will be completed by April 2023. Having these milestones set will ensure the team will be able to meet this deadline efficiently.

D. Gantt Chart

A Gantt Chart plays a critical role in any type of project planning. The Gantt Chart displays the phases expressed in the Work Breakdown Structure and each task related to the phases. It will allow for more efficient time management for the project since it shows the time periods where each task must be completed by. Other unexpected tasks can always be added to the Gantt Chart later if needed. The Gantt Chart can be used in any other project including the design of the Autonomous Lawn Mower to better organize and for future planning of individual or group projects. The team has utilized ProjectLibre for building the Gannt chart, the chart for the design of the Autonomous Lawn Mower is shown in Fig. 2.

E. PERT Chart

The Program Evaluation Review Technique Chart can assist project members in mapping out various timelines for a project, like a Gantt Chart. It gives a visual aid to project leaders and members of timelines including the start date, end date, duration, and anything else a certain task depends on. It helps to determine a path for all members that are a part of the project. Like the Gantt Chart, the team also used the ProjectLibre software to assist in generating the PERT chart shown in Fig. 3.

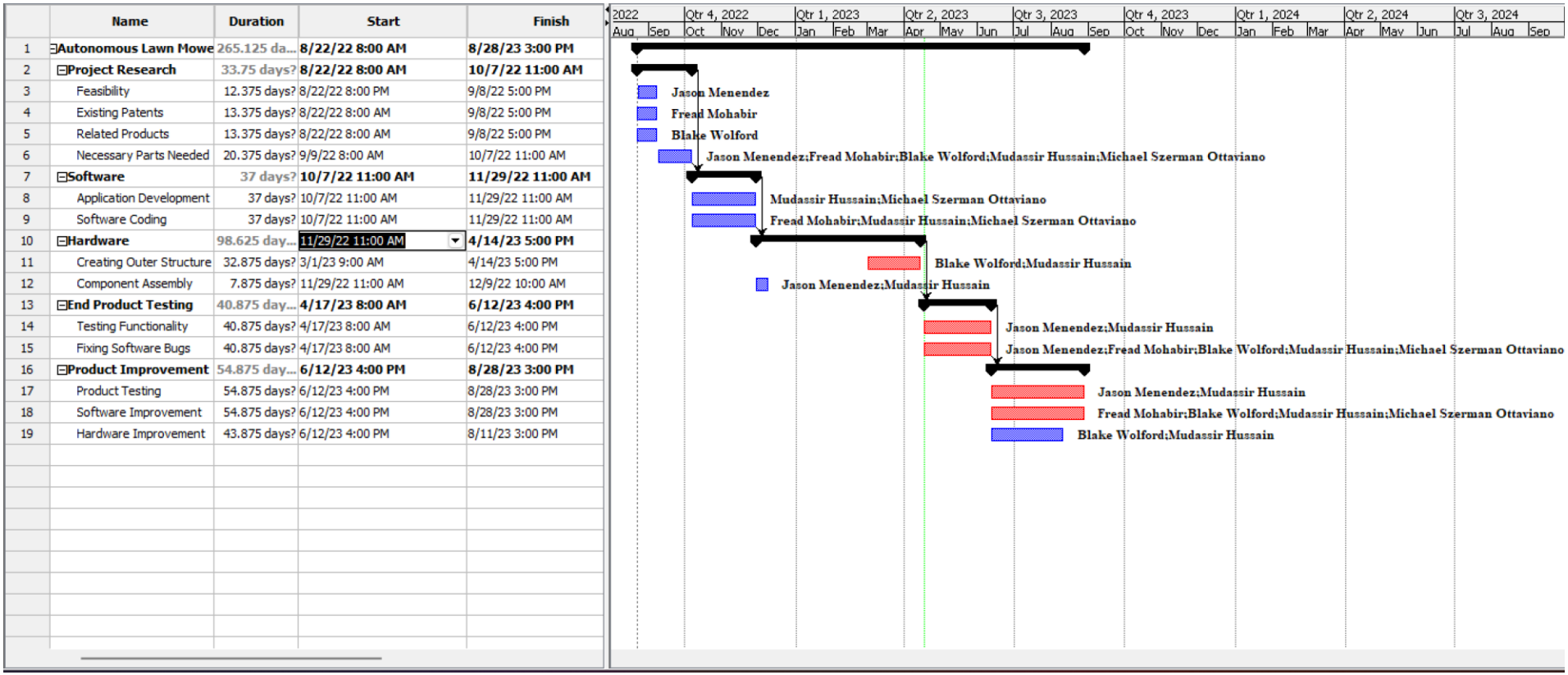


Fig. 2 Gantt Chart

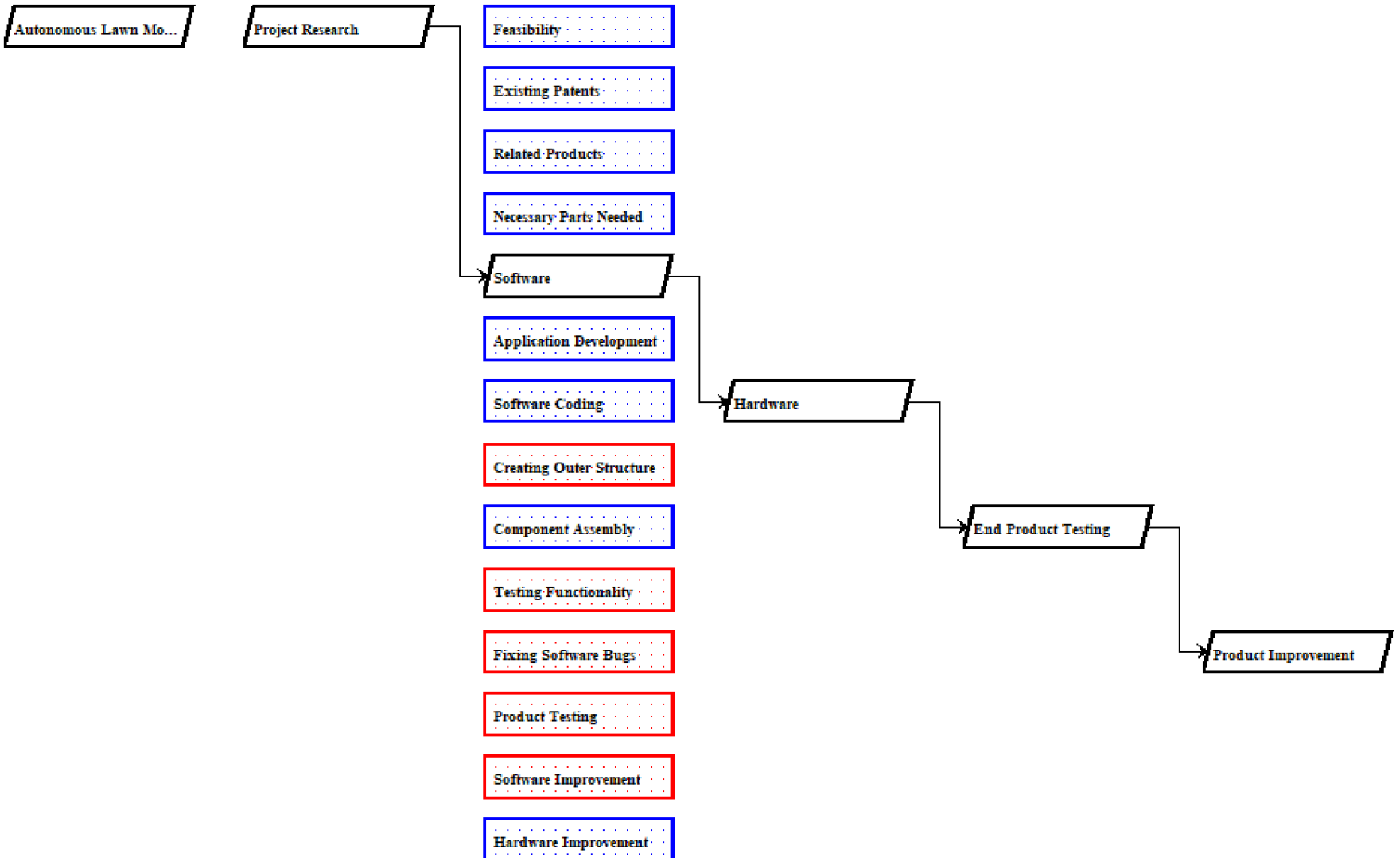


Fig. 3. PERT Chart

The plan of action has provided the Gantt and PERT charts specifically for the design of the Autonomous Lawn Mower. The Gantt Chart will help the team be time efficient with all tasks when it comes the software and hardware designs of the Autonomous Lawn Mower. Although both charts display deadlines for each task, the PERT chart displays more detailed dates when it comes to the deadlines of each task. As per the PERT Chart, the deadline to have the final product completed is April 17th, 2023. With the deadline date being so far out, it gives the team plenty of time to complete all tasks with little to no errors. The planning techniques used will ensure the team is able to offer the product within a timely manner to the consumer with no issues.

XX. MULTIDISCIPLINARY ASPECTS

In any complex undertaking, it is important to incorporate contributors with various areas of expertise, diverse perspectives, and wide technical competencies. In the case of engineering applications such as this project, particularly if those projects are maverick or even simply incrementally innovative in nature, it is vital to receive designs and implementation input from people of differing disciplines and fields. Our team has five members, each of which having a unique set of particular concentrations, abilities, strengths, proficiencies, and perspectives. This will be instrumental in achieving success with this project as it will allow each member to concentrate on exerting their individual strengths while also creating the potential for those strengths to compensate for shortcomings in other members. These strengths and weaknesses may be in the form of technical knowledge (e.g. electrical principles, programming languages, hardware/software design, etc.), or they may rather be related to project management/work styles and personality differences (e.g. various levels of organization, time management, language/writing or marketing skills, etc.).

It is eminently desirable to incorporate the finest and the most diverse sets of expertise available, and our team is fortunate enough to possess a wide array of varying and complimentary talent. Below is a brief exposé of each member's individual competencies:

Jason Menendez:

A. Electrical engineering discipline
B. Concentration on circuit analysis
C. Experience with programming in C
D. Experience with programming in C++

Fread Mohabir:

A. Electrical engineering discipline
B. Concentration in digital forensics
C. Concentration in networking and security
D. Experience with circuits
E. Experience with programming with C++
F. Knowledge of NEC

Mudassir Hussain:

A. Computer engineering discipline
B. Concentration in computer architecture and microprocessor design
C. Concentration in data system software
D. Concentration in embedding systems software
E. Strong knowledge of hardware/software interfacing
F. Knowledge of microcomputers
G. Experience with interfacing serial communication

Michael Szerman:

1. Computer engineering discipline
2. Concentration in computer programming & networks
3. Concentration in IoT Analytics with Python
4. Concentration in data structures with C++
5. Knowledge of discrete math and multivariable calculus
6. Strong background in app and server development with NodeJS and FastAPI

Blake Wolford:

- Electrical engineering discipline
- Concentration in power systems
- Concentration in data system software
- Concentration in digital forensics
- Concentration in nanotechnology
- Knowledge of hardware/software interfacing
- Proficiency in C, C++, Python, Javascript, and Java programming
- Experience in app design

Evidently, our team is composed of both electrical and computer engineers all of which bring to the team a balance of both hardware and software technical capabilities with specific concentrations. All members have programming experience and at least a basic knowledge of circuitry allowing broad contribution across the scope of the entire project from the design and construction of the mower itself to the coding of the app and integration with physical sensors.

This will help to ensure project success and completion as it allows the workload to be evenly spread amongst people with experience across a range of technical sectors spanning from forensics, networking, and security to circuits, power, and embedding processors.

In addition to technical know-how, our team also contains members of diverse strengths interpersonally that allow us to function well as a team. Michael Szerman is the team lead assisted heavily by Jason Menendez to keep team communication flowing and the project moving along on pace. By maintaining our current open lines of communication, our aim is to use them to facilitate in-person and online meetings (in-person in the case of those students who are local to the Miami area, and online being for the entire team as some members live quite far from FIU campus) for design, collaboration, device fabrication, testing, and documentation as our primary defense against falling behind given the break between semesters.

XXI. PERSONNEL

Michael Szerman | michaelszer@gmail.com
(786)867-2044 Florida 33160. Sunny Isles, US.

Education

Florida International University College of Engineering & Computing.
Expected Graduation: April 2023.
B.S. Computer Engineering, minor in Biology & Chemistry. **GPA: 3.92/4.00** in the Dean's List.
Technical School ORT. **Graduation Date:** December 2018.
Technical High School - graduated with a Technical Bachelor in Information and Communication Technology.
Achievements: Ranked #1 in Argentina in the Mathematics & Physics Olympics, #2 in Informatics, #4 in the National DaVinci Game Jam.
Acceptance into the **2022 Summer Research program in Rheology at Brown University** and **Google STEP Internship 2021**.
Created displayfy.co. The first real-time crypto & stock displayer in the U.S. for retail investors.

Work Experience

Software Developer Engineer Intern at Amazon, twice in different summers:

A. Exceed project expectations and objectives. Received return offer.
B. Connected the charity services from AmazonSmiles using Java, ObjectiveC & Python.
C. Written documentation of library features built in the Amazon internal programmers guide.
D. Fixed obsoletes setups from old environment preparation in internal walkthroughs.

Software Developer Engineer at Ripio, a South America n cryptocurrency wallet & exchange:

E. Drafted an action plan to build a scalable and progressive application.
F. Researched React Native libraries for face detection, multifactor authentication, and encryption.
G. Developed the mobile application in JavaScript with React Native from scratch.
H. Refactored server-side code in Flask Python to be compatible with mobile apps.

Relevant Projects

DisplayFy, crypto & stocks displayer for retail investors. Achieved price updates of less than 5 seconds.

I. Coded AWS Services for in-cloud computation and databases with AWS Lambda, DynamoDB & EventBridge. Prices were retrieved from Rapid API YH using AxiosJS.
J. Programmed Adafruit Metro M4 & ESP32 with C++. Communication with UART protocol.
K. Single-Page Application website with Vue & TailwindCSS.

DeFi Dashboard showing financial information about tokens in the Ethereum blockchain.

L. Started as part of the **Aave Data Lovers Hackathon.** Won honorable mention.

M. Collected transactions in real-time to calculate the Liquidity Pool and Volume of tokens.
N. Website: https://aave-data-lovers.herokuapp.com/

Skills and Activities

O. Fluent in English and Spanish. Coded in C++, C#, Java, Python, JavaScript, Solidity.
P. Worked with React, Vue, React Native, +ES6, Unity, NodeJS, Mac & Linux.

Mudassir Hussain | Mudassir9nine@gmail.com

(786)282-2875 Florida 33027. Miramar, US.

Education

Florida International University College of Engineering & Computing.
Expected Graduation: May 2023.
B.S. Computer Engineering, minor in Mathematical Science. **GPA: 3.20/4.00**.
Concentrations: Embedded System Software, Data System Software, and Computer Architecture and Microprocessor Design.

Work Experience

FIU Work-Study, Miramar, FL **Mar 2020 - Sep 2022**

Q. Student Assistant: Performed various tasks involving building operations.
R. Office duties. Assistance with computer Lab and technical issues.
S. Setting up and monitoring classrooms.

Ford, Sunrise, FL **Sep 2022 - Dec 2022**

T. Product Development Hardware Engineer Co-op: working with a design team to implement and validate circuits, analyze and resolve hardware failures and be responsible for meeting Ford's quality, on time, and maintaining cost targets.
U. Help with designing and testing of High-Speed digital circuit using industry-standard schematic capture tools to meet section requirements.
V. Handled validation testing and defined stress test routines. Completed worst-case analysis of circuits and generated documentation in area of responsibility.

Relevant Projects

MQTT Temp & Humidity Sensor **Aug 2021 - Nov 2021**

W. Modeled, designed, and created a small low-power consuming prototype that collects data of temperature and humidity using Losant Broker MQTT protocol.

Portable Ad-Blocker **Aug 2021 - Nov 2021**

X. Designed and implemented a portable device that blocks any unwanted content using a Raspberry Pi zero and Pi-Hole.

FPGA HDMI Signal Processing **Feb 2021 - May 2021**

Y. Implemented on a Zybo-Z7020, a device with real-time HDMI signal processing and modified to add various functions.

Skills and Activities

Z. **Software**: Intermediate knowledge of Xilinx, Fusion 360, Anysys, and Mentor Graphics.

AA. **Programming languages**: C/C++, Java, Python, VHDL, assembly, and Programming Embedded Systems.

BB. **Languages**: Engineering and Urdu.

Fread Mohabir | Fread_Mohabir@hotmail.com

(754)265-6633 Florida 33578. Riverview, US.

Education

Florida International University College of Engineering & Computing.

Expected Graduation: May 2023.

B.S. Electrical Engineering. **GPA: 3.45/4.00**.

Concentrations: Embedded System Software, Data System Software, and Computer Architecture and Microprocessor Design.

Coursework: C, C++, AutoCAD, Mastercam, Arduino, PSPICE, NI Multisim, Xilinx Vivado, FTK Imager, NEC.

Hillsborough Community College.

Graduated: May 2019.

Associates of Arts in Engineering. **GPA: 3.95/4.00**.

Work Experience

Amazon Fulfillment Center, Ruskin, Florida. **2017 - 2018**

CC. Receives items from shipments and prep for selling.

DD. ICQA Simple Bin and Cycle Count to make sure inventory is in correct location and available to fulfill the order of the customer.

EE. Stow items neatly in a specific location so units are added to inventory and are available to customers.

FF. Problem solves units that cannot be received under correct purchase orders or adds inventory that were shipped physically but not virtually manifested in shipment.

IT Equipment Coordinator Ruskin, Florida. **2018 - Present**

GG. Inventory Management and Asset Tracking.

HH. Computer troubleshooting and repair.

Blake Wolford | blakewolford813@gmail.com

(813)597-9032 Florida 33027. Miramar, US.

Education

Florida International University College of Engineering & Computing.

Expected Graduation: May 2023.

B.S. Electrical Engineering, minor in Mathematical Science. **GPA: 3.67/4.00**.

Concentrations: Power Systems, Data System Software, Digital Forensics, Nanotechnology, Hardware/Software Interfacing, and App Design.

Eagle Scout / Scouts BSA

Florida Academic Scholars (FAS) scholarship recipient / Florida Bright Futures

USF Director's Award scholarship recipient / University of South Florida

Work Experience

Chili's Grill & Bar, Server. **Mar 2021 - Present**

II. Clearly related listing information to guests.

JJ. Managed payments with a high degree of accuracy.

Outback Steakhouse, Server, Takeaway, Host and Buser. **Aug 2018 - Mar 2021**

KK. Handled high customer volume in a timely manner.

LL. Articulated key information in person and over the phone.

MM. Ensured customer satisfaction.

Chris Welbon Karate Clubs, Instructor. **Jun 2015 – Oct 2018**

NN. Communicated and demonstrated key concepts to student of all ages.

OO. Collaborated with other instructors to enhance student learning.

PP. Ensured safety of all personnel.

Jason Menendez | jmene073@gmail.com

(786)506-2311 Florida 33027. Miramar, US.

Education

Florida International University College of Engineering & Computing.

Expected Graduation: May 2023.

B.S. Electrical Engineering. **GPA: 3.67/4.00**.

Concentrations: Circuit Analysis, Systems Programming in C and C++.

Coursework: Signals & Systems, Circuits, C for Engineers, Computer Applications, Intro to Linear System.

Work Experience

Innovated Power Group, Technical Assistance. **Mar 2021 - Present**

QQ. Aided generator paralleling control panels for Miami Dade Water and Sewer.

RR. Aided with troubleshooting the generator's electrical control systems.

SS. Aided with troubleshot medium voltage switchgear protection systems for power generation.

TT. Ordered mechanical and electrical parts from a third-party vendor for various ongoing projects.

UU. Assisted program power manager controls.

Miami Metro Zoo, Sales Assistance. **Apr 2018 - Jan 2019**

VV. Aided with ticket sales and organization with events for the Zoo Miami such as Feast with the Beast, Zoo lights, and Brew at the Zoo.

WW. Became adept in using Excel and Microsoft Word.

XX. Compiled, prioritized, and sorted customers' orders into a local database.

Skills and Activities

YY. Experienced in breadboard circuits and circuit analysis.

ZZ. Experienced in C/C++ programing language.

AAA. Experience in electrical design through previous employment.

XXII. BUDGET

The Goal of this section is to discuss the budget of the overall project. It's crucial to do an analysis of the budget to determine what budget the whole team needs to determine and whether the project is feasible to build within that budget. The team will evaluate the components along with determining the budget. In an engineering environment, various components are needed to build the overall product, and prices go up quickly for the build, which is why this section is extremely crucial for the project's future. The components will be bought through various vendors and the prices will be listed in the following TABLE XXXV. The team will be splitting the total cost among the five members evenly.

TABLE XXXV. Budget Table

Materials	Quantity	Price
7in Wheels	2	$16.99
Universal Battery Charger	1	$45.00
High Torque DC Motor 12V	2	$33.04
Arduino UNO	1	$54.98
24V 5000mAh battery	1	$48.49
Wheel and Blade Mounts	3	$23.37
LM2596	1	$12.88
HC-SR04 Ultrasonic Sensor	3	$8.99
3D printer filament	2	$37.98
3in swivel wheel	1	$25.99
Mower Blade	1	$12.99
DC motor for Blade	1	$13.49
Arduino Sensor Shield Expansion Board	3	$8.49
Motor Driver	2	$16.99
3D Printer Nozzle	1	$11.99

Wires and Connectors	1	$45.16
Motor Mounts	3	$26.97
Total Amount	--	$443.79

The Arduino UNO presented in Table.XXXIV will take into consideration the current prices on the market. Prices are not definitive and are subject to changes as time goes by. After the careful analysis of the required component and searching for vendors and their prices, the team has concluded with the required cost of individual components along with overall cost of the project. It's determined that the project would cost around $443.79 at the current moment.

XXIII. RESULT EVALUATION

In this section, an explanation will be given on how the results of the product will be evaluated in Senior Design II. The evaluation of the results will be based on the promises that will be made this semester on the Objectives to be met, Constraint to satisfy, standards to follow, patents not to infringe upon, and specifications. This comparison will be done in Senior Design II, but in this section, we will address how the teams plans on evaluating everything.

A. Objectives

It was already addressed that the objectives of the product revolves around assembly, user friendliness, safety, and marketability. In Senior Design II, the evaluate the results the team will be looking at the objectives and see whether they have been met. For assembly, it will be looked at weather overall assembly of the robots holds up in outdoor environments and is successful in protecting the circuitry from it. In user friendly, the team will evaluated that based on the ease of use of the mower for new users and the changing of the blades to maintain the robot. For safety, it will be seen how to robot carries out its safety functionalities such as using obstacles sensors to stop the robot if an animal or person is detected. For marketability, we will see how efficient the mower will be in collecting data such as voltages, current, and environment data.

B. Technical Results

The proposal stated that the mower will have GPS functionalities. Unfortunately, the GPS modules tested were too inaccurate to implement with the mower. Instead, the user will input the lawn dimensions into the application to determine where the mower will cut. Because of this, the smart mapping technology will not work. Ultrasonic sensors have been implemented with the mower to avoid obstacles. The application is also working for use with the mower.

C. Constraints

In Senior Design II, to truly evaluate the build of our product, it must be seen if the robot operates based on the constraints of the product. The team will evaluate whether the battery charge of the robot is able to last at least 40min of a session. Another base for evaluation will be on the robots navigation and roaming features, the team will survey how well the robot navigates the whole lawn with its navigation capabilities and using its sensors to avoid obstacles. The ability to detect water and how weather proof will also be assessed. One of the most important constraints for the team to evaluate is the app connectivity over longer distances.

D. Patents

For this part, the team will assess if the robot hasn't infringed on any patents. The team must closely look at the final design and patents for product similar to our robot such as the three listed in this report:

1) Autonomous Lawn Mower – US 20170181375A1
2) Autonomous Lawn Mower and a System For Navigation Thereof - US011172608B2
3) Lawn Mower Robot - US011096325B2

All these patents have many claims and some of them relate to the robot, so they must be compared to evaluate whether the robotic lawn mower has infringed on a patent or not. The team will mainly be looking at the navigation system, the cutting module, overall body, sensor functionality, and other more specific features.

E. Specification

The specification certain with quantitative values the final design must follow. The team will mainly evaluate how well the final design will follows the specifications. First to access is weather the robot operates on a microcontroller with WIFI and Bluetooth functions, at least 20 GPIOs and a CPU with 32-bit processing and 1GH clock speed. The overall body built will be looked at and its ability to withstand high temperature, UV, and water. The sensors will be tested to assess its ability to detect obstacles up to 50cm away. Lastly, the team will evaluate the overall weight and dimensions of the final design to see if it's under 30ib and 22in x 15in x 10in.

In conclusion, this section was about how the team will be evaluating the results of the final product and based on what bases. It was already established that the robot must meet certain objectives to be completed. The mower must be built under certain constraints so the mower can in best operating condition. To avoid legal issues, the team must looked at the final design for any infringement on patents of similar products. Lastly, the robotic lawn mower must have certain technical and design specification for easy manufacturing and have the most efficient build.

XXIV. Lifelong Learning

One of an engineer's essential professional and personal disciplines must be the willingness and desire to be a lifelong learner. Especially in a field such as electrical and/or computer engineering and in an age where technology iteratively improves upon itself at such staggering rates, the ability and capacity to take in new information, direction, and ways of solving older problems is a trait that is second to none. This sort of openness to learning and improvement has played an important role in the design—and will continue to play an important role in the fabrication—of this project as well.

As to the matter of fabrication, there are at this stage a handful of steps left to have the design production-ready. At present, approximately 20% of the hardware has been tested as a proof of concept demonstrating the mobility of the device and the navigation mechanism (primarily via GPS). This means that a finalized design and manufacturing method of the chassis as well as the mower blade mechanisms themselves will need to be prototyped, refined, and codified in formal plans to be combined with the functioning navigation system. Manufacturing and logistic considerations would need to be factored in as well at such a time as the design was complete, finalized, and there was sufficient impetus to prompt mass production.

On the learning front, there are myriad institutions, organizations, companies, societies, and otherwise within which an aspiring engineer may find themselves under further tutelage and within community of like-minded lifelong learners. The main one of these organizations being the IEEE (Institute of Electrical and Electronics Engineers), there is no shortage, especially in the current era of communication, of resources, standards, and networking to be had there. These sorts of things being at one's disposal are indispensable in the pursuit of ongoing education which in turn is of inestimable value to professional and personal development as well as in the successful acquisition of that which is necessary for various projects such as this to be successful.

This project has motivated the team to continue development of the mower even after the presentation. The team has had much success working together in developing the mower thus far. The team will continue to research other possibilities to make the mower design like no other and if possible, reach the production stage. Once this has been achieved, the team will be able to use this for as an accomplishment and will be able to utilize the research obtained from this project to implement other designs.

XXV. Conclusion

The idea of the Autonomous Lawn lower started even before our group was formed. When each of us started looking into the class we all were inspired by the previous projects before us. This was something that ignited our passion for this class in doing so we came up with many ideas that would be the best for our selected group. The team then started considering our mentor Gustavo Roig who was one of a few professors that we knew would be able to be flexible and have previous experience with circuit analysis. Then the team began to brainstorm on different things that we would be able to build, oddly enough the team came to the same conclusion that we wanted to create a device that would be able to be used by the everyday person. With our goal aligned we started thinking more specifically about what that device could be. As we prepared through the weeks the idea of the automaton's lawn mower came to us after hearing the concept of the "Good Life." This along with three other ideas was what set us on our path to accomplishing this device.

The team began working on the different prototypes that might be possible for us to create so that we can demonstrate our capabilities. Unfortunately, when we were starstruck by our idea we failed to consider the price of parts to accomplish our vision. This however didn't deter our goal of creating an autonomous lawnmower. It only proved to further push our design capabilities. Having a restriction in price made our group think more about design choices and what we can do with what we had. From the beginning, the team wanted to work on a project that would be able to contribute to the world and have a positive impact on society. This is the result of the team's intuition and resourcefulness.

After creating the reports needed for this project the team has a better understanding of what goes into creating products for the public.

Unfortunately, not all goals have been met at this time such as GPS and smart-mapping technology. This will not hinder the operation of the mower and the team will continue to meet all expectations of the mower as originally presented in Senior Design 1.

It has been an experience that was needed for our team to be able to develop our skills and allowed us to enjoy some of our final classes at FIU.

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APPENDICES

A. Team Contract

As a member of Senior Design Team 16

I hereby agree to the following conditions:

a. *To assist with my fair amount of the work necessary to obtain the end goal of the product and will be held responsible for failure to complete any assigned tasks.*
b. *Regardless of personal preference, a majority vote will be the primary decision-making process.*
c. *Maintaining communication with the team. If at any time I am not able to communicate, I must inform the team prior to not being able to communicate.*
d. *Disruption of the team's workflow and individual assignments of team members will not be tolerated.*

TABLE XXXVI. TEAM CONTRACT

Team Member Name	Signature	Date	Roles
Michael Szerman Ottaviano	MO	10/10/2022	Team Leader
Mudassir Hussain	MH	10/10/2022	Team Member
Blake Wolford	BW	10/10/2022	Team Member
Jason Menendez	JM	10/10/2022	Team Member
Fread Mohabir	FM	10/10/2022	Team Member

B. Intellectual Property Contract

As a member of Senior Design Team 16, we hereby agree to the following:

a. This contract has been approved by Michael Szerman Ottaviano, Mudassir Hussain, Blake Wolford, Jason Menendez and Fread Mohabir who are all a part of Senior Design Team 16.
b. Gustavo Roig is the dedicated spokesman for Senior Design Team 16.
c. The profit of the design will be distributed evenly across all members of Senior Design Team 16 if the design is to become a commercial product.
d. To come upon agreements, Senior Design Team 16 will cast a vote and will choose the majority vote as the decision-making process. All members MUST be aware that this vote will be taking place beforehand. If any persons shall not be present for the vote, their vote will be exempt.

TABLE XXXVII. INTELLECTUAL PROPERTY CONTRACT

Team Leader	Signature	Date
Michael Szerman Ottaviano	MO	10/10/2022
	Signature	Date
Mudassir Hussain	MH	10/10/2022
Blake Wolford	BW	10/10/2022
Jason Menendez	JM	10/10/2022
Fread Mohabir	FM	10/10/2022

XXVI. Signatures Page

Name	PID	E-mail Address	Phone Number
Jason Menendez	5634633	Jmene073@fiu.edu	786-506-2311
Fread Mohabir	6197003	Fmoha027@fiu.edu	(754) 265-6633
Michael Szerman Ottaviano	6205356	Mszer002@fiu.edu	(786)867-2044
Blake Wolford	6318687	bwolf019@fiu.edu	(813) 597-9032
Mudassir Hussain	6106675	Mhuss025@fiu.edu	786-282-2875

	PRINT	SIGNATURE	DATE
Group Leader	Jason Menendez	JM	4/17/2023
Team Member	Fread Mohabir	FM	4/17/2023
Team Member	Blake Wolford	BW	4/17/2023
Team Member	Michael Szerman Ottaviano	MSO	4/17/2023
Team Member	Mudassir Hussain	MH	4/17/2023
Mentor	Gustavo Roig	GR	4/17/2023