

GNC Modem Robot Control for Remote Garden Maintenance

ECE4015 Senior Design Project

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Executive Summary

The focus of this project is to design a mobile robot to remotely navigate a raised garden bed environment. The robot system will include features to analyze soil temperature and moisture, examine plants for disease, and mapping problematic areas in the garden plant beds, however the main goal of this project is to only design a mobile platform and navigation system for the robot.

The robot must be able to navigate the simple and diverse garden beds of various sizes with ease with the capability to overcome any terrain or weather in the garden bed area. The robot system will be able to navigate, survey, and maintain the garden bed from any location in the world using an application on a mobile device. The robot platform must utilize the Modern Radio GNC-Modem (Guidance, Navigation, and Control) to control the location and movement of the robot from the user interface controls within a geofenced area.

The robot will feature a long-lasting rechargeable battery for extended run times and traversing large garden areas and possess the ability to return to the charging/docking station autonomously. The robot battery must also allow the integration of future features needing constant power while the robot is navigating the garden. The robot platform must be small enough to pass between immovable objects while possessing excess space to mount future features on the platform for various tools to assist the user in maintaining the garden. The robot control interface must be simplistic and compatible with common mobile devices for easy and quick use at any time or user location. The location of the robot will be transmitted real time through the user interface to allow the user to navigate around the garden efficiently and quickly with ease.

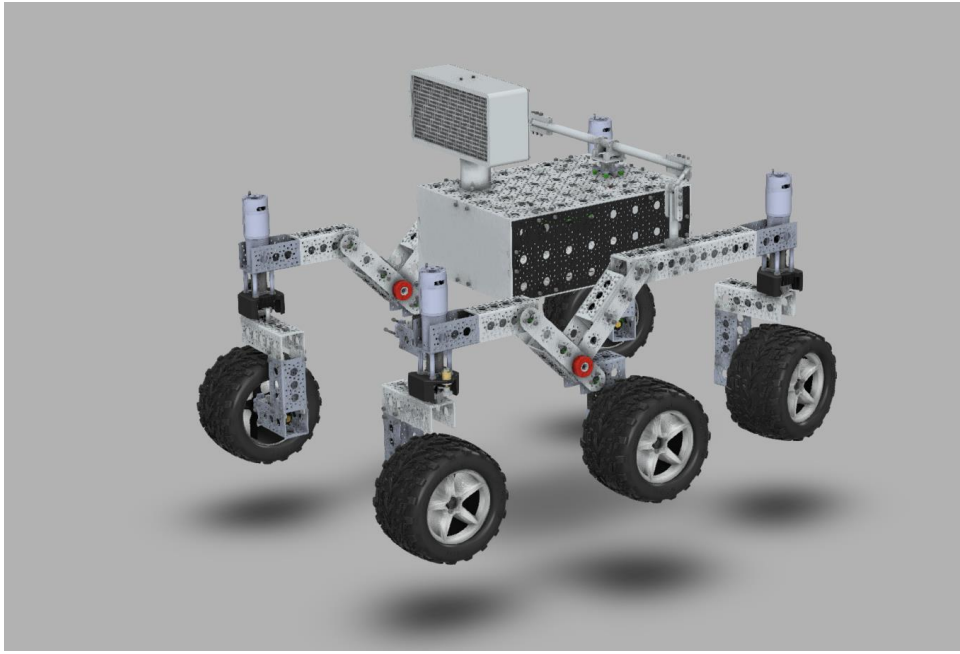


Figure 1: 3D rendition of design of the navigation robot

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1. Introduction

The GT Engineering group is requesting \$500 amount of funding to develop a mobile robot for Modern Radio (Hip-Sci). The objective is to create a mobile robot to remotely navigate through a raised garden bed to conduct analyses on the soil and plants of the garden. The scope of the GT Engineering group is to create a mobile platform and navigation system for this robot so that Modern Radio (Hip-Sci) can build on this progress and have a robot that is able to examine the garden.

Modern Radio (Hip-Sci) wants the ability to examine their garden without physically being there. To realistically accomplish this, a robot is being created to traverse across the entire garden and conduct whatever tests need to be done. The design of the robot is similar to the Mars rover due to its reputation for traveling across different terrain and conducting various tests. The intended use of the robot is to remotely control it so that it is able to conduct tests on the soil and plants of the garden. Although this is the intended use for the end product, the scope for the GT Engineering group is to have a mobile robot platform that is able to navigate remotely through the garden. The robot will feature a long-lasting rechargeable battery for extended run times and traversing large garden areas. In addition, it will possess the ability to return to the charging/docking station autonomously. The robot control interface will be simplistic and compatible with common devices so that it can be moved easily.

For a final project design, Modern Radio (Hip-Sci) will have a functional mobile robot platform and navigation system to traverse the robot through their garden. In addition, this design will be open source and will be published on GitHub for others to learn about the design of the robot. One technical issue that the GT Engineering group must overcome is the issue of power and ensuring that the robot has sustainable power. Another technical issue is having enough space for the GNC module and other components that the sponsor wants to add to the mobile robot platform. To combat the issue of power the group is installing a solar panel that will recharge the battery while the robot is

in sunlight. To address the issue of space, the group is ensuring that the robot has a big enough platform that will allow the GNC module to fit along with other components the sponsor will want to add in the future.

The remainder of the document will present a more in-depth project description with goals, technical specifications of the mobile robot, the GT Engineering group design approach with a Gantt chart, and a marketing and cost analysis of the project.

2. Project Description, Customer Requirements, and Goals

The goal of this project is to design a user-friendly remote-controlled rover to allow a user to traverse a garden from any location using a cloud service. The robot design will be weatherproof, have exceptional battery life, and be able to navigate difficult terrain found in various gardens. At the project completion, the resources for constructing, navigating, and communicating with the robot will be made open source to the public for easy access and application to any field. As the project progresses, electronic sensors for disease and pest identification with added cameras for remote inspection will be added to further enhance the rover's capabilities.

For this project the customer will be considered Hip Sci, the project sponsor, and prospective garden owners after the project is released to the public. The preliminary requirement for this project was that the Rover design must be centered around the GNC modem by Hip Sci. The GNC modem, short for Guidance, Navigation, and Control module will be the brain of the rover and responsible for controlling the rover systems and receiving inputs from the user for navigation. The modem is supplied by the sponsor along with an appropriate application programming interface to integrate the modem with other systems. There are several robots and rovers on the market, however, Hip-Sci is pursuing a platform that is versatile yet made for the specific task of monitoring a garden from any location in the world using a cloud service to communicate with the rover and the use. The target audience for this project ranges from small garden owners with plant rows or beds to large gardens with multiple species

of plants. Navigation of the rover will be accomplished with a simple user interface for the use on a mobile device and have a respectable speed for the rover be able to quickly navigate the garden and over any obstacles. Because of the intended purpose of the rover, the rover must have a long battery life and be able to recharge when not in use via a solar panel on the rover. It is expected that the rover will operate and be stored outdoors for its entire lifetime, thus the rover and its systems must survive any weather conditions. From these customer requirements, corresponding engineering requirements were set to accomplish the project goals.

Table #1: Customer and Engineering Requirements for Garden Rover

Customer Requirements	Engineering Requirements
Rechargeable Battery	Solar Panel Charger
Long Battery Life	Long battery life for extended usage
Traverse obstacles	Large wheels and articulating suspension
Space for Future accessories	Space to accommodate electronics inside rover
able to view all plants	Tall frame to view various plants
Operate entirely outdoors	Water and weatherproof systems
Integrate GNC Modem	Mandatory inclusion of the GNC modem
Control with phone	Controllable with mobile app
Wireless connectivity to rover and cloud from any location	Remote Communication with cloud service at all time
Software system able to integrate additional sensors	Flexible and versatile platform space
Easily repaired with simple tools	Simple construction and design

The project is funded by Hip-Sci thus the project cost and risk are fully assumed by the sponsor to make this project open source for final completion. This risk for the project sponsor can be visualized in the stake holder chart and table below. The design team will monitor the current products being offered for remote rover control and the need for a specific rover to inspect garden growth and life. The team will communicate with the project sponsor over the course of the term to update the progress of the project and customers. The design team will also be responsible for the project following all codes and standards for battery, data communication, and mobile app development. All stake holders and

design team together will help minimize the risk for the project sponsor and keep the project on target for open-source release.

Table 2: Stake Holders for Rover Project



Monitor:	Keep Satisfied:	Keep Informed:	Manage Closely:
Competing products	Hip-Sci sponsor	Hip-Sci Project lead	Project Risk to Hip-Sci
Market need for perspective product	Perspective owners	Project Codes and standards	Project completion date of open-source release

3. Technical Specifications

After setting the customer requirements and setting the appropriate engineering goals, a specification sheet for the Rover Design is used to guide the project goals to accomplish the customer requirements in Appendix Figure 1. The **Physical characteristics** is largely open ended for the Rover design, but it was determined that a goal should be set to make the Rover tall enough to view over raised plant beds and rows to allow the user to view all the plants in the garden adequately which was set at 18 inches. In the event of a major malfunction or the rover needs to be repaired, the target for the rover weight is 150 pounds or less to allow the rover to be moved physically. The **Electrical** specifications include the rover having battery life of 12 hours or more during extended use, a solar panel equipped on the rover for charging, and utilizing brushed motors for moving the rover across the garden at target speed of 3 mph greater for **Performance**. For the **Mechanical** aspects of the rover, the design must be fully weatherproof and survive extreme weather conditions. The rover must also be

capable of traversing difficult terrain as user gardens are in various conditions. Once the rover is open source, the rover must be of simple design and be possible to repair by all users in the event of malfunction. The project sponsor has mandated the inclusion of the GNC modem which will be implemented under **Software** specifications. The data communications from the rover to the cloud, ability to integrate future tools or sensors after open-source release and controlling with a mobile app along with the user interface will also be handled as whole by the design team.

To organize the design team's efforts to accomplish the sponsor and customer requirements, a House of Quality was employed to target the team's efforts in Chart #1 in the Appendix for the House of Quality. Here the customer and engineering requirements were ranked and analyzed for negative and positive relationships, correlations, and directions of improvement. Targets were set for each engineering requirement as goals to be accomplished for the rover design. As the project is developed, these requirements will change to better suit the customer and sponsor requirements to better suit the rover design. Using the Weight Chart in the House of Quality, the critical engineering requirements are noted as the following: integration of future tools and electronics, rover battery life, ability to traverse difficult terrain, and mandatory integration of GNC modem. The GNC modem is supplied by the project sponsor, Hip-Sci, and will be responsible for communicating the rover's position, navigation by the user, and communication with the cloud service. The rover battery life has a requirement of 12 hours or greater of extensive use, durable in severe temperature extremes, and compact to limit the size and weight of the rover overall. As further research is conducted into battery selection for the rover, it is desired to maximize the battery life of the rover even during extensive field use by the operator. For charging the rover, a solar panel charger with a charge rate to 2 amps will be equipped to the rover per the sponsor's requirements to allow the rover to be parked at any location in a garden and recharge the battery for next use. Since the project is to be released to open source, the project sponsor desired the rover feature the ability to integrate easily with future hardware and software accessories added to the rover for further development and improvement. This includes space for components inside the rover

for sensitive electronics, as well as outside the rover on the body for additional sensors. It should be noted that the solar panel charger proposed for this rover will have an impact on the space afforded to the outside of the rover, thus the design team will be maximizing the space available. For the rover to successfully navigate in the garden, the suspension system of the rover must be able to traverse over obstacles such as hoses, ruts, sticks, plants, fallen vegetation, and more to allow the user to reach any area within their garden boundary.

4. Design Approach and Details

4.1 Design Concept Ideation, Constraints, Alternatives, and Tradeoffs

The design consists of Modern Radio GNC-Modem (Guidance, Navigation, and Control), Modern Radio sensors, Modern Radio IOT stick, high-resolution Wi-Fi cameras, and Raspberry Pi microcontroller. Raspberry Pi will be set up as the controller for the robot, where in reads input signals from a joystick (for testing) and mobile devices after testing. The GNC-Modem will be set up to allow cellular devices to control the location and movement of the robot from the user interface application controls within a geofenced area. Additional features to analyze the soil temperature and moisture, examine plants for disease will be implemented with the Modern Radio sensors and IOT stick. The final stage of the design will be the set-up of the WIFI camera system to enable users to remotely control the robot anywhere in the world.

In designing the body of the robot, the main factors considered were durability, size, and water-resistant. In terms of durability, we want the robot to withstand extreme temperatures, casual drops, and mechanical stress. This robot is subject to remaining outdoors, so it will be useful for it to function in severe weather conditions such as rain and snow. Our plan is to 3D print these parts using reliable materials.

The major computing aspect of this project is designing a mobile platform to navigate the robot and make use of its analytics features. The software team will be responsible for dealing with the hardware-

software interface and creating a user interface application that is easy for consumers to use. The HW-SW interface will focus on programming the Raspberry Pi as the main controller for the robot and its internal I/O peripherals in our system. The UI application will then be created, interfacing with the Modern Radio GNC modem. This application will be responsible for navigating the robot and gathering information from several sensors that can be easily understood without technical experience.

For this robot, our approach is to it an open-source project. The software will be available on GitHub, electrical and mechanical details of this project will also be available and published on GitHub and other platforms.

4.2 Preliminary Concept Selection and Justification

The team began the selection process began with meeting with the sponsor and determining what has already been decided on and what is still being discussed. There are four design aspects that were known upon receiving the project. A modular robot chassis decided by the sponsor will be used, a raspberry pi will control the robot, the JPL API will be used, the robot will be controlled remotely over cellular, and the robot will be charged via solar panels.

The team was given the responsibility of determining the type of rechargeable battery, what kind of motor will drive the wheels, and the motor controller. Beginning with the type of motor, the group considered the following criteria: reliability, torque, top speed, and complexity. The team determined a brushed DC motor was the best compromise of all the criteria compared to stepper motors and brushless DC motors. A decision on the size and power of the motor has not been decided because there is still uncertainty about the total weight of the robot, the size of the wheels and the range of terrain it will be traversing. The team then chose a motor controller based on what type of libraries were included, its compatibility with the raspberry pi and compatibility with the motors. The motor controller was a generic motor hat for brushed motors with python libraries. The criteria for selection of battery type are the following: reliability, safety, scalability, and complexity. It was

decided the Panasonic 18650 lithium-ion battery would be the perfect fit but haven't decided how many will be required due to other unknown factors.

Due to the design factors that haven't been determined, there are a couple of potential risks that could be realized. The first risk is the motors not being large enough. The actual weight of the robot has not been calculated, the size of the wheels is not known, and the intensity of the terrain is not known are significant contributors to this risk. Fortunately, due to the simplicity of DC brushed motors, the motors can be switched out for higher output ones. This leads to the other potential risk: the size of the battery. Going back to the unknown factors previously stated, it is unknown how large the battery pack needs to be to provide the robot with adequate operation time per charge. This risk can easily be mitigated by adding units to the battery pack. Due to the modularity of the Panasonic 18650 batteries, adding additional units to the pack is a simple and straightforward process.

4.3 Engineering Analyses and Experiment

In creating our prototype, there will be numerous amounts of tests and evaluations. The first step will be to decide requirements for the various components including power, circuit and mechanical requirements. Once that has been set, we will go ahead and inspect those requirements to ensure they have all been met. For the actual testing of the robot there will be two major stages. The first stage will be the manual control of the robot with hardware interface, and the second stage is the testing of the cellular controller. During the first stage a gaming controller will test out the movements of the robot, using a gaming controller the robot will read in several other inputs to test out the sensor features. In the second stage of testing cellular devices will be used to test the UI application, in the stage the robot should be fully controlled using cellular devices. It should be able to translate the data gathered from the various sensors and lastly test the use of the camera system to determine the robot's location remotely. Testing will occur on different texture surfaces outdoors.

4.4 Codes and Standards

A list of several standards that will affect the design decisions of this project include:

- UL 1642 – Standard for Safety for Lithium Batteries
- ANSI/NEMA C18 – Safety Standards for Primary, Secondary and Lithium Batteries
- UL 2054 – Standard for Household and Commercial Batteries
- UL1004: Establishes general requirements for all types of electrical motors.
- 1641 - IEEE Standard for Signal and Test Definition

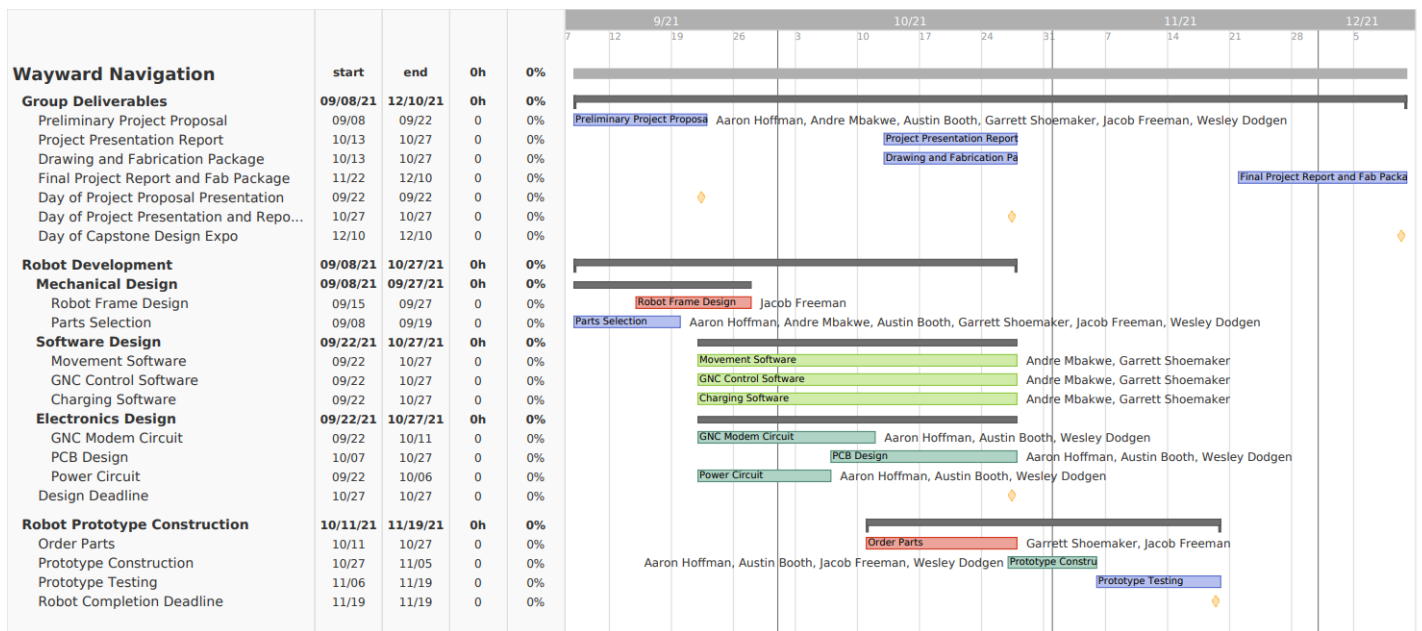
5. Project Demonstration

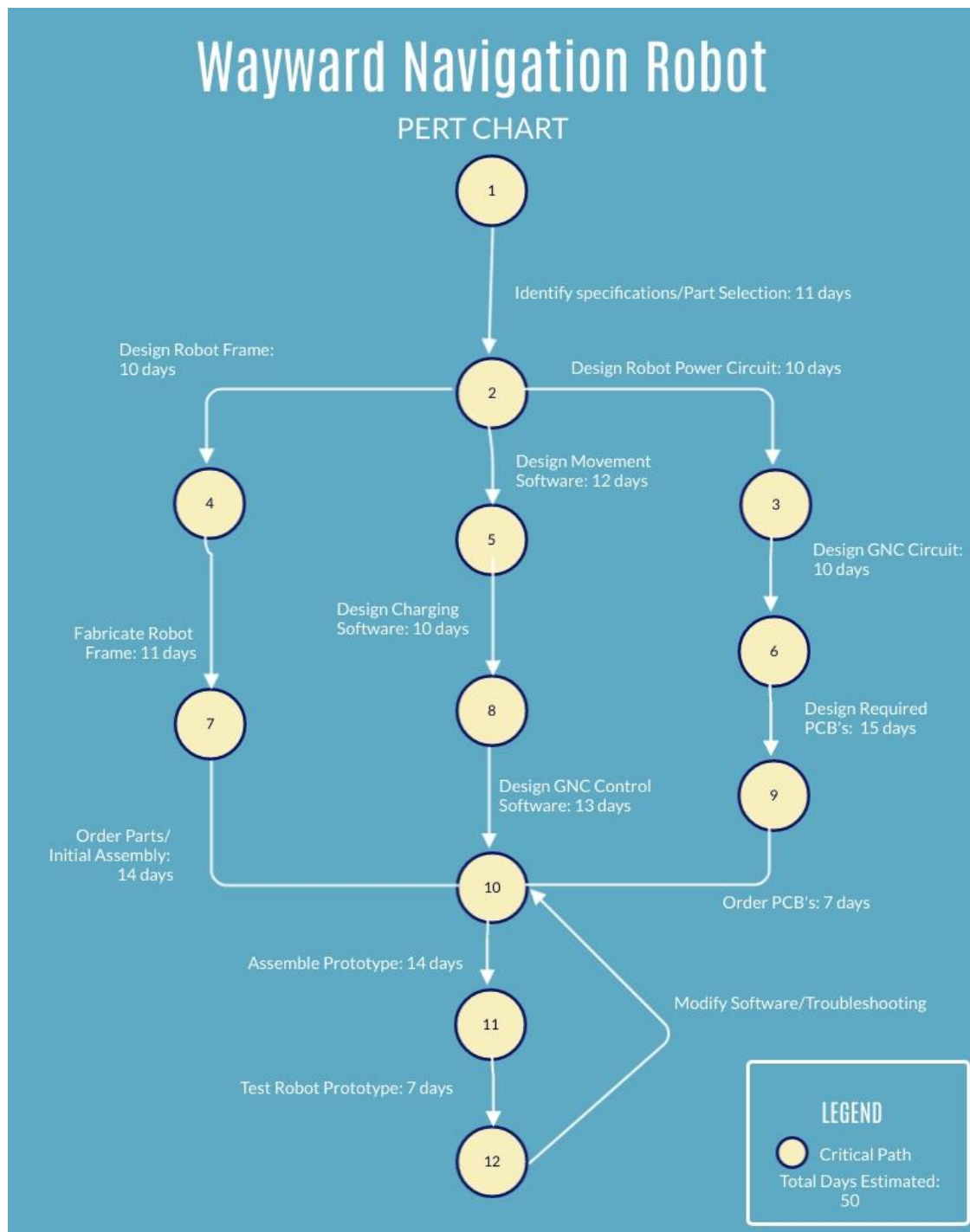
Our final project demonstration will consist of the modern radio robot being remotely driven and controlled using an app on a cell phone. This validates the following:

- Developed software that controls and harmonizes hardware to successfully drive robot
- Utilizing DC motors, DC motor controller, sensors, and raspberry pi to drive robot
- Operating robot remotely
- Operating robot over cellular

6. Schedule, Tasks, and Milestones:

Team Schedule Gantt Chart





After estimation of both the timeline and critical path, the team estimates a 95% chance of successful completion of the project according to the timeline above. The lack of 100% certainty of completion primarily stems from the possibility of unexpected problems that could arise from the testing and assembly phases.

7. Marketing and Cost Analysis

7.1 Marketing Analysis

The market for DIY robots is relatively unsaturated, but some competitors like the Yahboom Professional DIY Robotics Kit and Picar-B Mars Rover [6],[9]. At a price of \$138.99 and \$72.24 respectively, these options include collision sensors, real-time video transmission, and can be controlled via mobile applications. The Team's robot sets itself apart with improved control range, self-charging capabilities, and weather resilience. With a sufficient internet connection, the control range is effectively limitless thanks to a built-in GNC-Modem. Solar Panels installed on the robot allow for self-charging and a reinforced frame protects the electronics from inclement weather conditions. This product will be open source, allowing anyone to build their own robot or modify the design to suit their needs.

7.2 Cost Analysis

Cost Analysis			
	Hourly Rate	Days	Total
Labor	\$19	50	\$950
	Cost	QTY	Total
Frame	\$30	1	\$30
Motors	\$15	4	\$60
Motor Hat	\$23	1	\$23
PCB	\$18	1	\$18
Solar Panel	\$10	1	\$10
Battery	\$7	4	\$28
GNC Module	\$20	1	\$20
Wiring	\$15	1	\$15
Light Sensor	\$8	1	\$8
Servo	\$10	2	\$20
Wheels	\$19	3	\$57
Materials			\$289
Final Cost			\$1,239
Product Price			\$0

The cost of labor and materials was determined by looking at the average salary of engineering interns in Atlanta, GA and searching for relevant parts on the internet [3],[4],[5],[7],[8].

8. Current Status

We are currently at the end of the planning phase of our project and the beginning of the design phase. We finalized our hardware selection with our sponsor and have begun designing the layout of the robot's hardware, and the architecture of the software. We are 20% through our assigned tasks with the bulk of the work still ahead of us in this phase we are beginning.

9. Leadership Roles

- **Garrett Shoemaker:** Webmaster and Team Liaison - Responsible for weekly email updates and communication between sponsor and design team.
- **Andre Mbakwe:** Software Team Lead - Responsible for all software deliverables and development along with ensuring software development is on schedule.
- **Austin Booth:** Mechanical Team Lead - Responsible for all mechanical deliverables and ensuring mechanical deliverables are on schedule
- **Jacob Freeman:** Team Lead - Responsible for ensuring the team is on schedule and coordinating with team leads.
- **Aaron Hoffman:** Financial Manager - Responsible for marketing and cost analysis
- **Welsey Dodgen:** Electrical Team Lead - Responsible for all Electrical/hardware deliverables and ensuring deliverables are on schedule.

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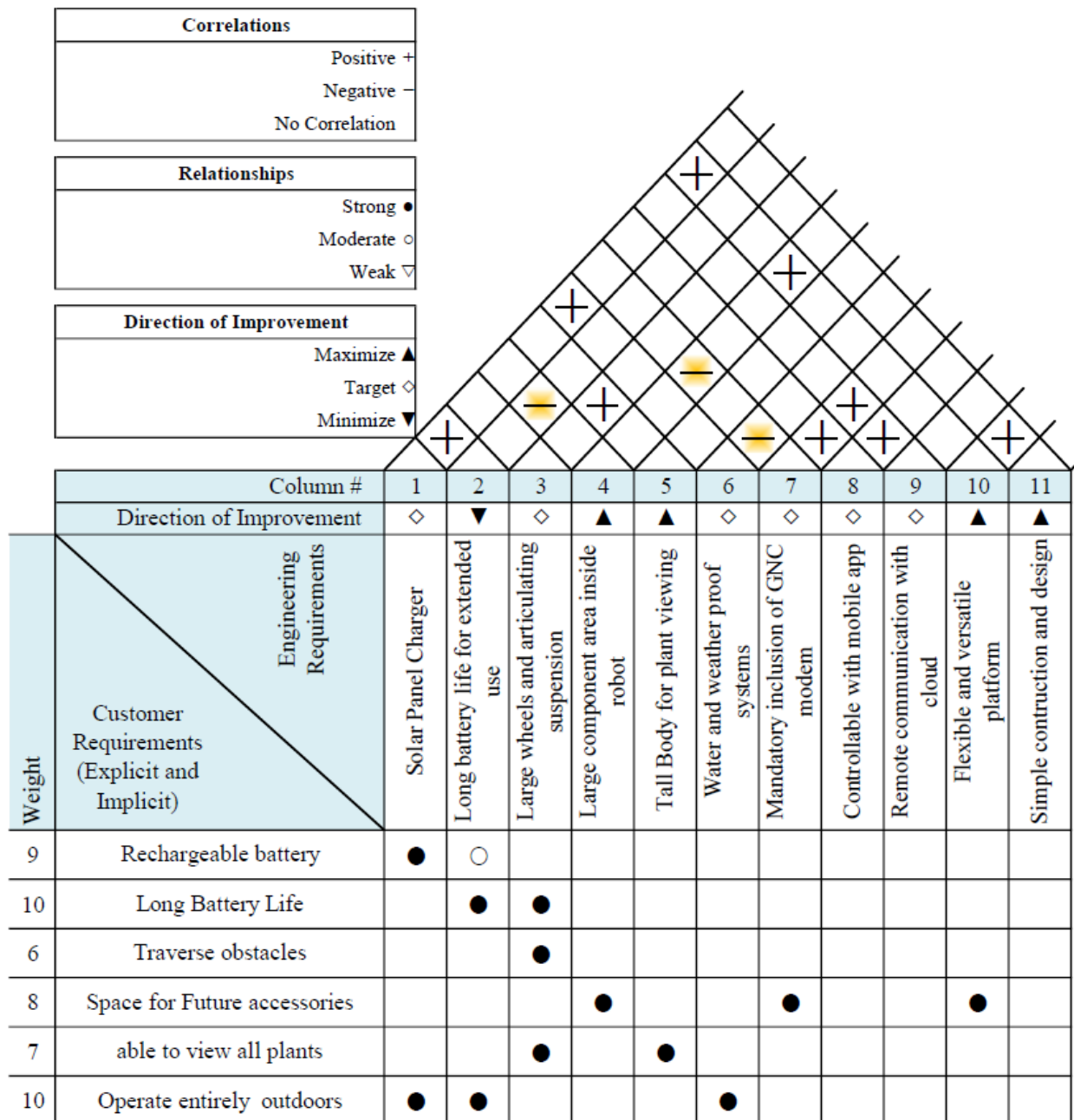
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Appendix:

Chart 1: Rover House of Quality [10]



10	Integrate GNC Modem				○			●			●	
8	Control with phone								●	●		
9	Wireless connectivity to robot from any location							●	●	●		
7	Software system able to integrate additional sensors		●		●						●	●
6	Easily repaired with simple tools										●	●
Target		Charge rate of 2A	Battery life of 12 hours of extended	10" diameter wheels to traverse	must fit battery, support	overall height 18"	Completely weather proof	Include GNC modem	Develop phone app to control	Ability to have continuous	Accept aftermarket and	Inexpensive components
Max Relationship		9	9	9	9	9	9	9	9	9	9	9
Technical Importance Rating		171	270	207	165	63	90	243	153	153	279	117
Relative Weight		9%	14%	11%	9%	3%	5%	13%	8%	8%	15%	6%
Weight Chart												

Figure 1: Rover Specification Sheet [11]

			Issued: 9/17/2021			
			For: WayWard Navigation Rover		Page: 1	
			Specification			
No.	Date	D/W	Requirements	Responsible	Source	How Validated
Physical Characteristics						
1	9/10/2021	W	Tall body to view plants in garden beds (18')	Mechanical Team	Hip Sci	view all plants
2	9/10/2021	W	Light Weight construction for Rover < 150 lbs	Mechanical Team	Team	
Electrical						
1	9/10/2021	W	Long battery life of 12hrs or greater	Electrical Team	Hip Sci	Endurance test
2	9/10/2021	D	Solar panel recharge the battery	Elect/Mech Team	Hip Sci	Recharge battery
3	9/10/2021	W	Brushed motors for movement (motor/wheel)	Electrical Team	Team	Power Output
Mechanical						
1	9/10/2021	D	Traverse difficult terrain (Hoses, Ruts)	Mechanical Team	Hip Sci	"Road" test
2	9/10/2021	W	Simple construction and repairable by user	Mechanical Team	Team	
3	9/10/2021	D	Weatherproof (Heat, Cold, Rain, Acts of God)	Mechanical Team	Team	Element Test
Software						
1	9/10/2021	D	Integrate GNC modem (Provided)	CompE Team	Hip Sci	
2	9/10/2021	D	Communicate with Cloud Service (TBD)	CompE Team	Hip Sci	Connectivity test
3	9/10/2021	W	Control with phone app (TBD)	CompE Team	Hip Sci	UI testing
Performance						
1	9/10/2021	W	Capable of moving 3mph or greater	Elect/Mech/Comp	Team	Speed trial
2	9/10/2021	W	User friendly controls for easy navigation	Elect/Mech/Comp	Hip Sci	UI testing
3	9/10/2021	W	Ability to integrate additional features by user	Elect/Mech/Comp	Team	Space and electrical