Reverse Engineering Robotics
Final Proposal

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DISCLAIMER

1 EXECUTIVE SUMMARY

We are tasked with reverse engineering the Super Droid GRT 1000 [1] mobile explorer robot with a budget of $1500.00. The team is tasked of replicating a tracked robot no less than 1:2 scale of the originals design while providing similar performance outputs of the original design. The capstone teams design must incorporate styling and manufacturing process such as sheet metal bending, Computer aided design and other manufacturing process to complete our proposed design by the month of December 2022 for the completion of ME (Mechanical Engineering) 486C Senior capstone design at Northern Arizona University.

Our capstone team's designs take inspiration from the original but modified to meet our time and budget constraints provided by our client. Using Solid Works CAD, we can design a two-motor system of 7:10 scale. The design will be a tracked robot with two geared wheelchair motors. Our design encompasses many of the original electronic components with an emphasis on the chassis and drive system to meet the size and cost requirements. The team plans to utilize lightweight materials such as aluminum to keep the overall weight of the design as minimal as can be. The following figure is an exploded view of our proposed design plan.

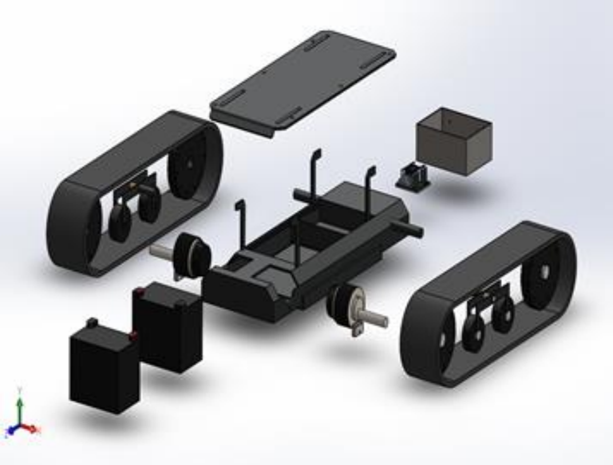

Figure 1:Exploded View of Proposed Design

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2 BACKGROUND

2.1 Introduction

As part of the goals of the NAU Mechanical Engineering school, students will improve their learned skills into a multidisciplinary project which will turn us into a resourceful, creative, and well-prepared professional. While you are reading this paper, you will be aware of the work that TEAM 1 of the ME486 class has been doing during this first part of the Spring 2022 term. This time, we were assigned to a Reverse Engineering project, sponsored by the NAU Mechanical engineering department and our direct client Professor David Willy. Achieving this project will mean a lot of things, for example the next generation of capstone courses will have a good reference to work, get a didactic material to get involved into the area, the modernization of the school infrastructure and having more than one device of this kind.

2.2 Project Description

Meeting with our clients gave us the opportunity to know their needs and the general project description. As Professor Willy mentioned, the main purpose of the team should be to reverse engineer the project to get a duplicate of the original model as accurately as possible. He also mentioned the possibility of modifying some of the subsystem or dimensions if it would make it more accessible to the budget, which was reduced by 75% than the original model's price. This opened the window to the changes comes with the fact that this new device, would be use for the interior of the engineering building as part of the bottom of an intelligent assistant and eventually to help the students at the Mechanical Engineering school to interact with this device.

3 REQUIREMENTS

In this section we will discuss the Customer requirements and Engineering Requirements needed to complete this project. The customer requirements provided in section 2.1 will list the requirements given to us by our sponsor David Willy, David tasked us with these in mind of redesigning an entire robot design. To do this most of these requirements are focused on the reverse engineering processes. To fulfil these customers' needs the team needed Engineering requirements that would meet the demands of these customers' needs. In this section you will see a breakdown of these requirements as well as a House of Quality that values these requirements.

3.1 Customer Requirements (CRs)

Here you will find a list of customer requirements given to us by our sponsor David Willy. When explaining our project to us Professor Willy put an emphasis on this reverse engineering project being as accurate to the original design as possible. It is for this reason these requirements weighed so highly. Our requirements were:

1. Cost within the budget of $1,500
2. Durable and Robust design
3. Reliable design
4. Safe to operate
5. Provide Same Function as Original
6. Cosmetic Resemblance
7. Complete Bill of Materials
8. Has same components as Original
9. Functional Prototype

These requirements are all weighed very highly in our House of Quality (QFD) because of the emphasis on being as accurate as possible to the original design. The budget of our capstone project must not exceed $1,500.00 so this was weighed at a 9 on a 1-9 scale on the QFD chart. With our given budget we are expected to create a durable and robust frame that not only will provide durability to the robot, but also support a payload requirement of the original robot. For these requirements we rated this at a 7 on a 9 scale. This is important to the team, but we feel like if we use similar materials, it will be easy to provide a rigid frame to support our design.

Whenever excessive amounts of electricity are involved, safety is a major priority. This category would receive a 5 on our QFD chart if it were given as a customer need. The original design as a breaker built in that will cut if it exceeds a certain amperage. We plan to use the same breaker box so this robot will be safe to operate for future users.

Professor Willy tasked us with these requirements with the sole purpose of redesigning the original, our design must provide the original functionality while also looking like the original scale robot. For this reason, we gave these requirements a score of 9 on our QFD plot because at the end of the day if it does not perform like the original, we just made a robot and did not complete the goal of this project. By the end of this project Professor Willy would like a functional prototype that can be used for future learning endeavors in the mechanical engineering department, to be featured in classes such as 286 and 386 design courses.

3.2 Engineering Requirements (ERs)

In this section you will find the engineering requirements and how the team plans to verify these requirements. Our Engineering Requirements for this project are:

1. Length [ft.]
2. Weight [lbs.]
3. Torque [lbf.]
4. Power Consumption [W]
5. Max Payload [lbs.]
6. Reliability
7. Durability

We hope that with these engineering requirements we can meet all our customers' needs for this reverse engineering project. We plan to manage Torque output by the power going into the system times the number of drive motors we have on our design. We can tell how efficient our design is with some power consumption analysis by reading the amount of Watt hours each component in our design takes. We can add these minus the losses due to heat and get our overall power consumption on this project. We feel if we follow the length, weight, and overall dimensions of the original design we can get a design the meets the ER's of reliability and durability. In the next section shows the House of Quality QFD where these Customer needs and Engineering requirements were compared against original designs.

3.3 Functional Decomposition

For this project, the main three systems we plan to be focusing on are the electrical system, the track and wheel system, and the main frame system. In doing this we developed a black box model to fully illustrate how these systems work at a global level and how each form of energy interacts to make the robot perform its tasks. Next the functional model will be shown to illustrate the subfunctions and how they are all integrated into one system.

3.3.1 Black Box Model

The Black Box model is an integral component to understanding how a device works and operates. It is known that mechanical devices can be overly complicated when breaking them down into a functional model. To do this we use the Black box model to break down material, energy, and signal flows. In the figure below we have listed the input and outputs of each of these flows.

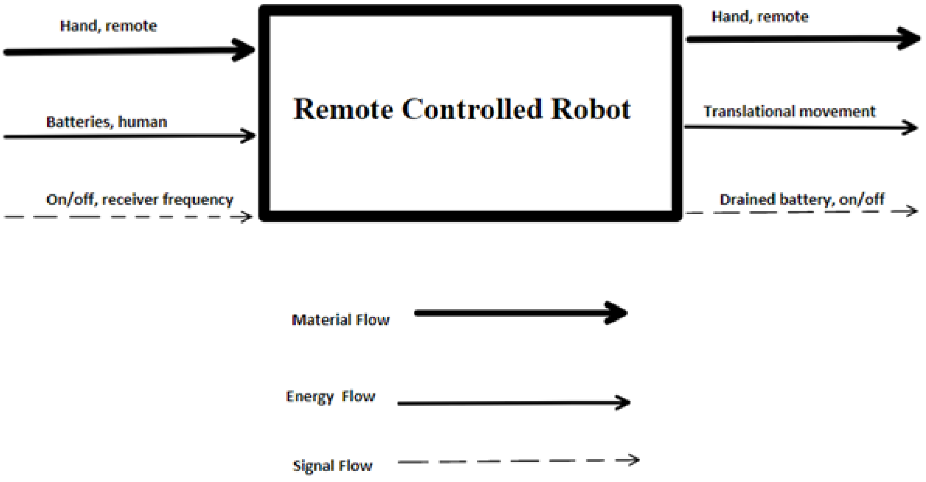


Figure 2: Black Box Model

3.3.2 Functional Model/Work-Process Diagram/Hierarchical Task Analysis

A step past the black box model we can examine the individual components that make up our design. This functional decomposition flow chart lists the major subcategories and components that make that major sub function. For our project we examined 4 sub functions, the frame, electronics, motors, and drive assembly systems. However, the updated version keeps the motors and the electronics all in one box. This helped the team to visualize the main components of this progress and how we can break up this project into more manageable sections. Below you will find our Functional model of the remote-controlled robot.

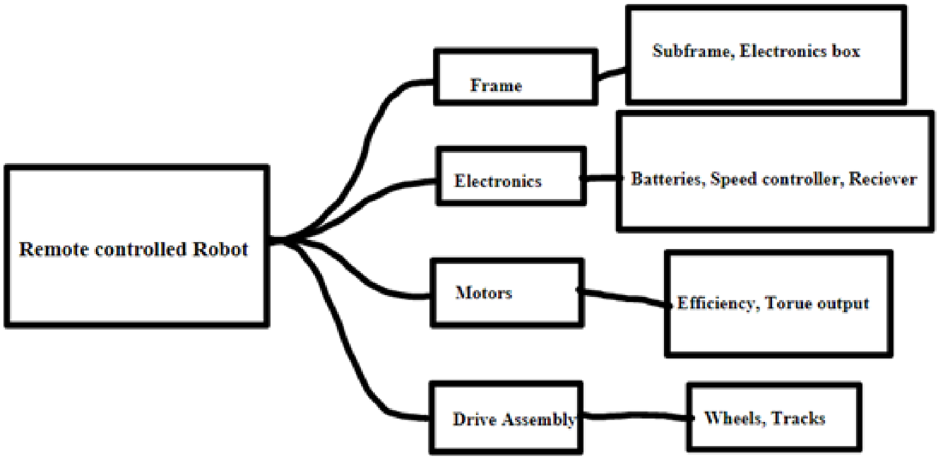


Figure 3:Functional Model

3.4 House of Quality (HoQ)

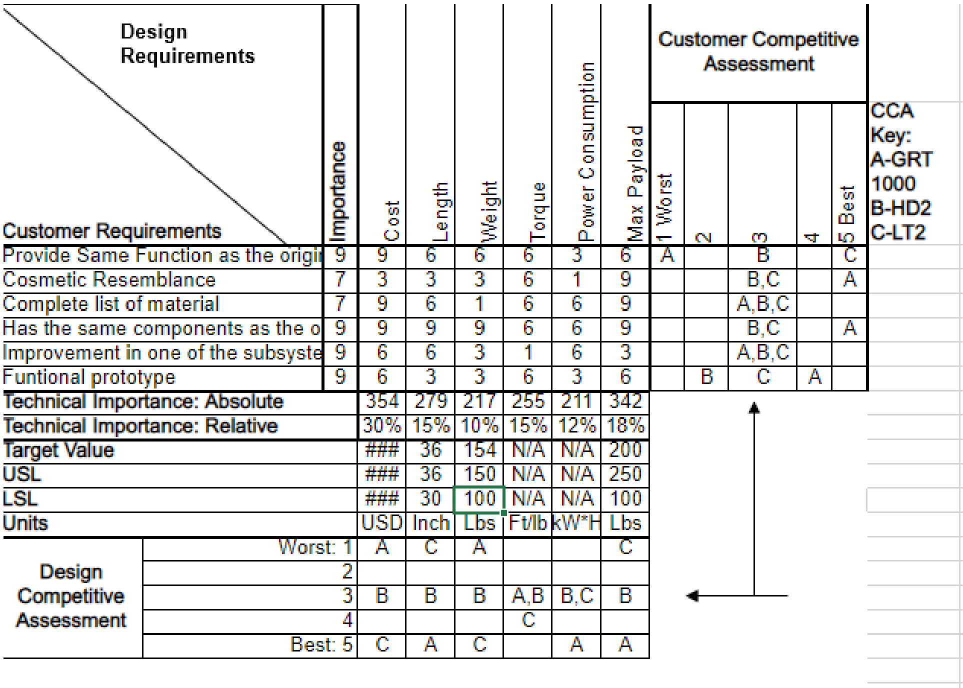
[Summarize project requirements in a House of Quality using the template provided on the course website. If the HoQ is small enough you may include it here as landscape or portrait. If it is too large, add the HoQ as an Appendix. Include a detailed introduction to the section and a discussion of how the HoQ has helped the team in the design process. Be specific and detailed (i.e. do not write any statements that could be applied to multiple projects besides your own). Ensure that every Engineering Requirement has a legitimate target value and tolerance to the target.]

[Include Testing Procedures in the House of Quality for this report.]

The house of quality is an essential tool for determining engineering requirements to meet customer needs. The house of quality for our project helped determine these key engineering requirements of sizing, torque and power consumption and maximum payload. These key engineering requirements' will help ensure the overall cost of our project is within budget and that all customer needs are met. In our project it is crucial that we can design and manufacture a robot that checks all the boxes, that can still perform adequately compared to the original design.

In our house of quality (HoQ) our design requirements are designed in a way that these values will be measurable during the testing phase of our project. The key design requirements that would require external testing are power consumption, maximum payload and safety. In the following figure 3 displays our HoQ comparing the original robot design. Noted in the key as design A. To two similar smaller scale robots. These robots provided great information on power consumption and torque values. Since all three designs were fairly similar besides scaling the team decided the robot with the best dollar to performance ratio would be the one we would attempt to replicate.

Design A will be the design we follow through with in this project. We plan to execute this by purchasing similar components as the original design, but scaling the overall size to meet the price requirements of the team. Table 1 denotes the testing procedures and the corresponding design requirement. In section 3.6 we will cover an in-depth overview of the design requirements and testing procedures.



Design Requirements / Customer Requirements	Importance	Cost	Length	Weight	Torque	Power Consumption	Max Payload	Customer Competitive Assessment: 1 Worst	2	3	4	5 Best
Provide Same Function as the origi	9	9	6	6	6	3	6	A		B		C
Cosmetic Resemblance	7	3	3	3	6	1	9			B,C		A
Complete list of material	7	9	6	1	6	6	9			A,B,C		
Has the same components as the o	9	9	9	9	6	6	9			B,C		A
Improvement in one of the subsyste	9	6	6	3	1	6	3			A,B,C		
Funtional prototype	9	6	3	3	6	3	6		B	C	A	
Technical Importance: Absolute		354	279	217	255	211	342					
Technical Importance: Relative		30%	15%	10%	15%	12%	18%					
Target Value		###	36	154	N/A	N/A	200					
USL		###	36	150	N/A	N/A	250					
LSL		###	30	100	N/A	N/A	100					
Units		USD	Inch	Lbs	Ft/lb	kW*H	Lbs					

Design Competitive Assessment		Cost	Length	Weight	Torque	Power Consumption	Max Payload
	Worst: 1	A	C	A			C
	2						
	3	B	B	B	A,B	B,C	B
	4				C		
	Best: 5	C	A	C		A	A

CCA Key:
A-GRT 1000
B-HD2
C-LT2

Figure 4:House of Quality

Table 1: Testing Procedures HoQ

Design Requirement	*Testing Procedure*
Power consumption	1
Maximum Payload	2
Reliability	3
Safety	4

3.5 Standards, Codes, and Regulations

- Standards and Codes that will be applied to our project located in table 2. Below is a list of the Standards and codes being applied to our project. The bulleted list covers each organization covered in table 2.

- Aluminum Association (AA)
- American Gear Manufacturers Association (AGMA)
- American Iron and Steel Institute (AISI)
- American National Standards Institute (ANSI)
- American Society of Mechanical Engineering (ASME)
- American Society of Testing and Materials (ASTM)
- American Welding Society (AWS)
- American Bearing Manufacturers Association (ABMA)
- Institute of Electrical and Electronics Engineers (IEEE)
- International Standards Organization (ISO)

Table 2:Standards of Practice as Applied to this Project

Standard Number or Code	**Title of Standard**	**How it applies to Project**
AA/ASTM B209	Standard Specification for Aluminum and flat sheet and plate	Our design may encompass the use of aluminum sheet metal. This standard specifies that the faces of the sheet metal we use have a milled finish.
AGMA 945-1-B20	Splines Design and Application	Helps in the design of how the drive wheels will interface with the motors in a safe manner.
ANSI/AGMA 6134-C21	Practice for Enclosed cylindrical worm gear speed reducers and gearmotors.	Our design uses two gearmotors to propel our design. This standard is helpful when choosing the correct motor, no greater than 3600 rpm.
ASME Y14.5	Dimension and Tolerancing	Our project involves a lot of parts such as splines that will have tolerance that must be met to ensure the proper fit of components against mate. This standard overview the dimensions and tolerancing of our project.
ASTM A 359	Methods and Definitions for Mechanical Testing of Structural Steel	Our design will have a structural steel frame these methods and definitions combined with FEA analysis will allow us to test the strength of the steel in our design.
AWS D1.1	Structural Welding Steel	Our project will have welded components made from steel sheet metal bent and welded to make the chassis and brackets
AWS D1.2	Structural Welding Aluminum	Our project will have welded components made from aluminum sheet metal bent and welded to make the chassis and brackets
ABMA STD 9	Load ratings and fatigue life for ball bearings	Our design will have two ball bearings to support the front idler wheels. These ball bearings will have to support the axle in our project.
IEEE 835-1994	Power Cable Ampacity tables	This table specifies dielectric power cables rated for high voltage applications; this will help the group. This standard describes a numerical method by which core and surface temperatures of cables interact with a system.

ISO 24351	General Requirements of three-dimensional modeling for mechanical products	We will adhere to ISO and ANSI standards for our CAD drawings as specified by the client. We will have a full cad package and bill of materials complete with drawings on this project.

3.6 Testing Procedures (TPs)

This section overviews the various testing procedures that will be completed next semester in ME 486 Capstone 2. These testing procedures were reached by obtaining key engineering requirements and customer needs. The following sections will cover an overview of each testing procedure, as well as a list of items needed to complete the experiment. And how this will be implemented into our schedule.

3.6 Testing Procedure 1: Power Consumption

In this testing procedure we will test the power consumption and draw on the system of various loads while the system operates under different conditions. This test will prove to satisfy the engineering requirement for power consumption. From this test we hope to gain data for how long the battery will last when placed under these loads. The schedule for this test will be run once the robot is in prototype phase with all major subsystems attached to the robot, so the design is at its ideal weight while under load.

3.6.1 Testing Procedure 1: Objective

For this test, the use of a multimeter or ammeter will measure power consumption while doing various tasks such as, driving, turning, inclines while under and loading with and without added weight on the chassis. This is important to our aspect of the project because we plan to have an ideal battery life of around 30 minutes with moderate driving underload. To know if this is possible, we need to know how much power the system is drawing during these actions.

3.6.2 Testing Procedure 1: Resources Required

[Provide a complete description of necessary items for the test to be completed satisfactorily. This includes (but is not limited to): people, software, hardware, tools, location, etc.

Resources for this test include a digital or analog multimeter or ammeter that will measure current draw on a circuit. This test can be run with two people. One person would ideally perform different tasks with the robot while the other recorded the average power consumption into a spreadsheet. This test can be run on a multitude of terrains and environments to find the average power consumption. This test should not be run during unideal weather conditions to limit damage to electronics subsystems.

3.6.3 Testing Procedure 1: Schedule

This test should take roughly 1-2 hours for setup and data collection. This is designed into our second semester schedule to take place at the 66% project completion phase during the testing portion of the capstone weeks 11-12.

3.7 Testing Procedure 2: Maximum Payload

This test we will determine the maximum safe payload our design can handle while undergoing various tasks such as driving on flat or inclined surfaces.

3.7.1 Testing Procedure 2: Objective

The objective of this experiment is to determine how much weight our design can handle within limits of our chassis and frame. The goal of this experiment is to identify a safe max load the design can carry while still being able to achieve ideal battery life and top speed requirements.

3.7.2 Testing Procedure 2: Resources Required

The complete robot design will be required to complete this testing procedure. Software such as Solid Works or Finite Elemental Analysis (FEA) analysis will determine the theoretical load that our frame and chassis can withstand. Mass will be added to the design to see how the robot reacts to added load. This testing procedure will be completed alongside the power consumption testing procedure. One person would ideally perform different tasks with the robot while the other recorded the mass added to the system and how it performs into a spreadsheet. This test can be completed on a multitude of terrains and environment. This test should not be completed with unsafe or unideal weather conditions.

3.7.3 Testing Procedure 2: Schedule

This test should take roughly 1-2 hours for setup and data collection. This is designed into our second semester schedule to take place at the 66% project completion phase during the testing portion of the capstone weeks 11-12.

3.8 Testing Procedure 3: Reliability and Durability

Our design must be reliable and durable. In this testing procedure we will test key components such as the wheels and idlers for deformation by applying horizontal and axial loads, as talked about in machine design and other engineering courses.

3.8.1 Testing Procedure 3: Objective

The objective of this experiment is to test the overall reliability of our proposed design. The driving system is a key component that will face many stresses and overall, the largest form of failure on our project. Since the wheels of our project will be 3D printed, we will need to ensure that these will be reliable while under load.

3.8.2 Testing Procedure 3: Resources Required

For this testing we will test our drive wheels under load conditions in the laboratory for delamination or shearing of the material. Different 3D printer filaments such as Polylactic acid (PLA) and Polyethylene terephthalate glycol (PETG) will be tested on the 3D printed wheels to see which one performs the best under loading [2]. The engineering laboratory for advanced composite materials would provide an excellent workspace for strain gauge data to test these crucial components. This is subject to change as we have not reached out to the lab instructor yet for access to their laboratory.

3.8.3 Testing Procedure 3: Schedule

This testing procedure will take place early next semester once the final design for the wheels has taken place. This testing should be completed by week 6 of second semester capstone ME 486. This testing should take 10 hours to complete by testing different material strengths and their deformation properties.

3.9 Testing Procedure 4: Safety

Safety is a top priority on this project as this project will be used in future classrooms as a learning aid. The objective of this testing procedure is to ensure fail safes built into the system work properly when a failure may occur.

3.9.1 Testing Procedure 4: Objective

For this project key failsafe mechanisms will be tested by cutting the power to critical electronics subsystems. Power will be lost in a number of ways including circuit breaker tripped and loss of connection from transmitter to receiver. It is important to note in the final wiring of the design, electronics components and wires will be secured properly to ensure no shorts in the system can occur, which could lead to possible electrical fires or destruction of components.

3.9.2 Testing Procedure 4: Resources Required

For this testing procedure the electronics portion is required. The electronics portion is comprised of the

Batteries, circuit protector, electronic speed controller, receiver and transmitter, and electric gear motors. Electronic fail safes are in place that will allow the design to shut off if the design gets too warm or connection is lost to the speed controller or receiver modules. The circuit protector ensures that if to many amps are drawn on the system the fuse will disable the design if anything were to go wrong. This can be done in any location with enough space to operate the robot.

3.9.3 Testing Procedure 4: Schedule

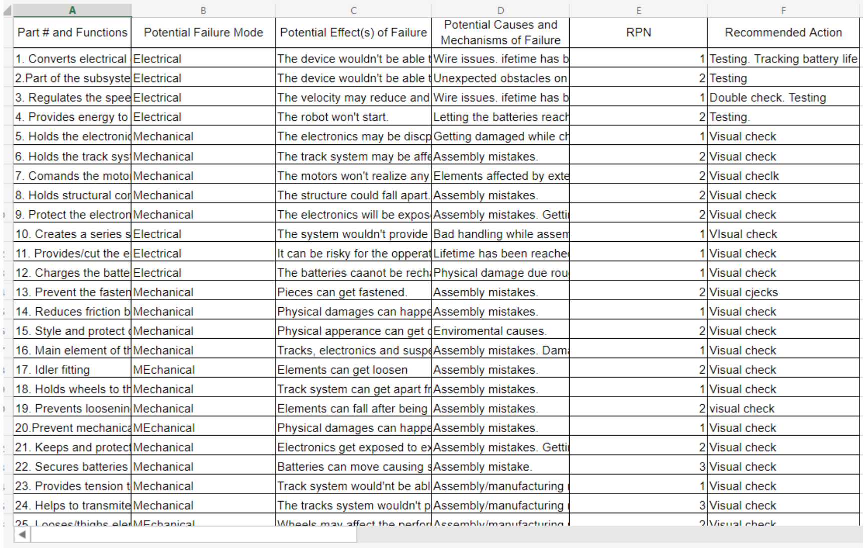
This portion of testing procedures can be completed as soon as possible, because our electronics portion is complete, and the built-in failsafe have been tested this semester we will not need to test these again till the final assembly of our design to ensure the failsafe is working properly.

4 Risk Analysis and Mitigation

4.1 Critical Failures

Its really important to know the potential failures of a system that we are analyzing. For this case, we have gone through all the elements of the Bill of Materials and look for their possible situations for failure. In the paragraphs below we can see the different cases present in our design.

In the next image, you can have an overview of the FMEA applied to the project.



A	B	C	D	E	F
Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Potential Causes and Mechanisms of Failure	RPN	Recommended Action
1. Converts electrical	Electrical	The device wouldn't be able	Wire issues. ifetime has b	1	Testing. Tracking battery life
2.Part of the subsyste	Electrical	The device wouldn't be able	Unexpected obstacles on	2	Testing
3. Regulates the spee	Electrical	The velocity may reduce and	Wire issues. ifetime has b	1	Double check. Testing
4. Provides energy to	Electrical	The robot won't start.	Letting the batteries reach	2	Testing.
5. Holds the electroni	Mechanical	The electronics may be discp	Getting damaged while ch	1	Visual check
6. Holds the track sys	Mechanical	The track system may be affe	Assembly mistakes.	2	Visual check
7. Comands the moto	Mechanical	The motors won't realize any	Elements affected by exte	2	Visual checlk
8. Holds structural co	Mechanical	The structure could fall apart.	Assembly mistakes.	2	Visual check
9. Protect the electron	Mechanical	The electronics will be expos	Assembly mistakes. Getti	2	Visual check
10. Creates a series s	Electrical	The system wouldn't provide	Bad handling while assem	1	VIsual check
11. Provides/cut the e	Electrical	It can be risky for the opperat	Lifetime has been reache	1	Visual check
12. Charges the batte	Electrical	The batteries caanot be rech	Physical damage due rou	1	Visual check
13. Prevent the fasten	Mechanical	Pieces can get fastened.	Assembly mistakes.	2	Visual cjecks
14. Reduces friction b	Mechanical	Physical damages can happe	Assembly mistakes.	1	Visual check
15. Style and protect	Mechanical	Physical apperance can get	Enviromental causes.	2	Visual check
16. Main element of th	Mechanical	Tracks, electronics and suspe	Assembly mistakes. Dam	1	Visual check
17. Idler fitting	MEchanical	Elements can get loosen	Assembly mistakes.	2	Visual check
18. Holds wheels to th	Mechanical	Track system can get apart fr	Assembly mistakes.	1	Visual check
19. Prevents loosenin	Mechanical	Elements can fall after being	Assembly mistakes.	2	visual check
20.Prevent mechanica	MEchanical	Physical damages can happe	Assembly mistakes.	1	Visual check
21. Keeps and protect	Mechanical	Electronics get exposed to ex	Assembly mistakes. Getti	2	Visual check
22. Secures batteries	Mechanical	Batteries can move causing s	Assembly mistake.	3	Visual check
23. Provides tension t	Mechanical	Track system would'nt be abl	Assembly/manufacturing	1	Visual check
24. Helps to transmite	Mechanical	The tracks system wouldn't p	Assembly/manufacturing	3	Visual check
25. Looses/thighs ele	MEchanical	Wheels may affect the perfor	Assembly/manufacturing	2	Visual check

Figure 5. Short FMEA

4.1.1 Potential Critical Failure 1: Motors

The motors play an essential role in the design. They provide the movement needed to displace the robot from the original position to the desired position. If they fail, it might mean that the robot would stay in the same position. The best way to prevent this actions are to keep a track of the motor’s use and make visual checks periodically.

4.1.2 Potential Critical Failure 2: Batteries

As we can imagine, batteries are in charge of provide energy to the whole system. Is the batteries fail, theres no energy provided to any other subsystem. To prevent this, its important to never let the batteries get to their lowest level and also keep a track of the battery life.

4.1.3 Potential Critical Failure 3: Speed controller

The speed controllers are useful to control the velocity of the robot. The first and most common sign that this is failing is the fact that it doesn’t go as normal speed, going every time lower. Its important to keep a track of it’s lifetime and also be ready to replace when needed. It’s important to mentioned that environmental conditions and physical damages may affect the development of this device.

4.1.4 Potential Critical Failure 4: Tracks

This elements are essential to move the robot from one point to another. If this element of the tracks system fails, that means that the robot keeps unable to move. Due the complexity of this element, the easiest thing to do is keep a second pair of tracks.

4.1.5 Potential Critical Failure 5: Receiver/Controller

The main use of the receiver/controller set is to communicate the motors to the batteries, allowing to give exact directions to the motors guided to the remote. This is a simple device and easy to replace, which it wouldn’t represent a big issue. If failing, the best option is to replace the device.

4.1.6 Potential Critical Failure 6:Frame

The frame is the main structure of the robot, on its top it would hold all the electronic and alectrical devices and on the sides it would support the track and suspension system. This is a really critical part, and the only moment when it could fail would be after a long time or if it gets under a really high load/force. The best way to prevent this is to just keep an eye on the payload.

4.1.7 Potential Critical Failure 7: In/Off switch

This is such an important device due to it’s secures the operators safety. To turn the robot on, the operator have to move the switch to the on mode. If the switch is not working it could mean that the robot can be started even before the operator noticed and get hurted. The main reasons this part of the sys tem could fail is due to environmental conditions or bad use of the elements.

4.1.8 Potential Critical Failure 8: Electronics box

The electronics box keeps all the electronics safe from the environmental conditions and isolated from the other subsystems. It can only fail if the box breaks due to a bad management of it or if it gets hit for something else.

4.1.9 Potential Critical Failure 9: Battery tie down

This helps to keep the batteries in the same position. This is critical cause if theres any movement into the frame of the robot some elements can be displaced from its original position and affect the development of some others.

4.1.10 Potential Critical Failure 10: Large wheels

This wheels are part of the track system, and their main function is to provide rotation to the track system. The main reason this could fail is on the assembly process, reason for why its highly recommended to double check that everything looks good and test it.

4.2 Risks and Trade-offs Analysis

Once gone through the critical failures, we have noticed about the difficulties to face all the different possible failures listed in the last point and the ones in the FMEA design. In general, all of these difficulties can be easily handled if there's a periodically maintenance to the robot and if we don’t overwork the main functions of it. Also, many of the risky components are easy to get.

5 DESIGN SELECTED – First Semester

For this chapter, the focus will be on the current state of the design and how the plan for this design can be backed up with mathematical formulas to validate the process. The first section is the design description, and this section will show the design we produced as well as justifications on why we picked this design. This section will also include a prototype to further illustrate the validation of the design. The last section is the Implementation plan and how we will work to produce the product as well as the most recent CAD drawings.

5.1 Design Description

For our final design we decided to make a few major updates to the current design. The major one is that we are sticking with just two motors instead of the four that had originally been with the robot. These two motors still have more than enough torque to move the robot with the load as shown by the calculation below.

$$F_f = m \cdot g \cdot \mu = 431.64 \text{ N} \quad \text{(Eqn.1)}$$

$$T_w = F_f \cdot r = 41.00 \text{ Nm} \quad \text{(Eqn.2)}$$

The main updates to the frame include streamlining it to take the complexities out of the Manufacturing process as well as make the overall weight of the frame lighter. Another change to the robot is the addition of one idler instead of two. With our scaling of 75% we do not have the need to have two idler sets and one will suffice for the length of the tracks we plan to get. Below is the prototype that we built for our final presentation. This prototype includes all the electrical components as mentioned in the functional decomposition. This prototype solved a noticeably big problem for us as we did not know how all these systems work with one another. By solving this circuit, we are now able to control the motors via remote control.

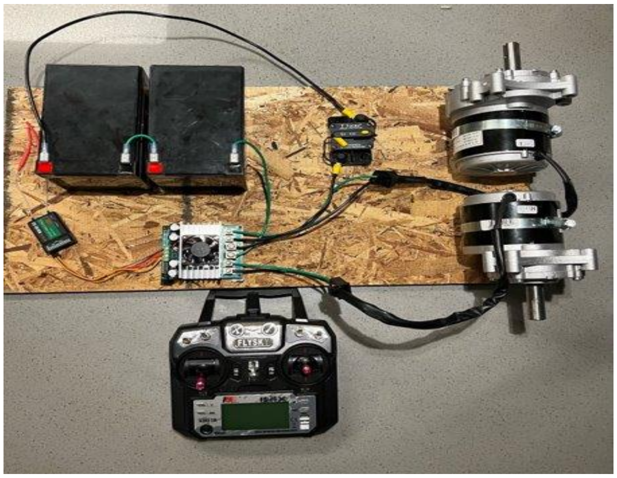


Figure 5: Prototype Electrical System

5.2 Implementation Plan

To manufacture our robot, we plan to do this in three stages. The first stage is to order our tracks these will be outsourced and be custom made to accommodate this one-off project. The reason for this is that this will drive the project as they will determine the final length of the robot. Next, we plan to 3-D print all our wheels and idlers. This semester we have the CAD of these wheels and are 3-D printed for a prototype. The final plan is to manufacture the frame. We plan to do most of the fabrication at the machine shop, but we could outsource the welding to be done by a professional. As seen below the frame is what is holding the entire assembly together and this will take the longest to get the geometry correct, so we plan to spend a good amount of time in the machine shop completing. The exploded view of the design can be seen below with the main components highlighted. As mentioned before the critical system of the frame will be our focus in semester two.

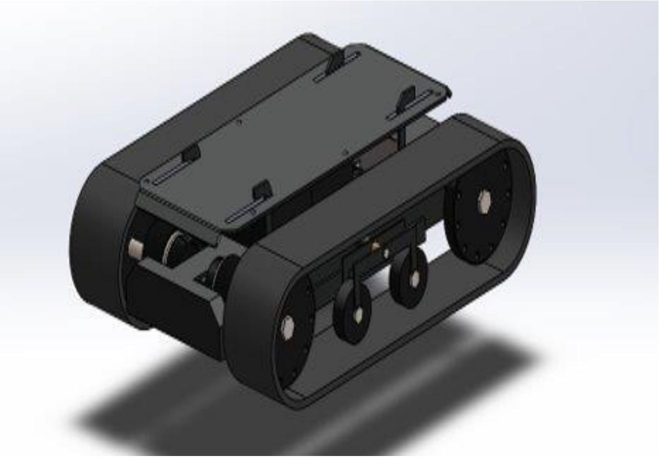


Figure 6: CAD Final Design

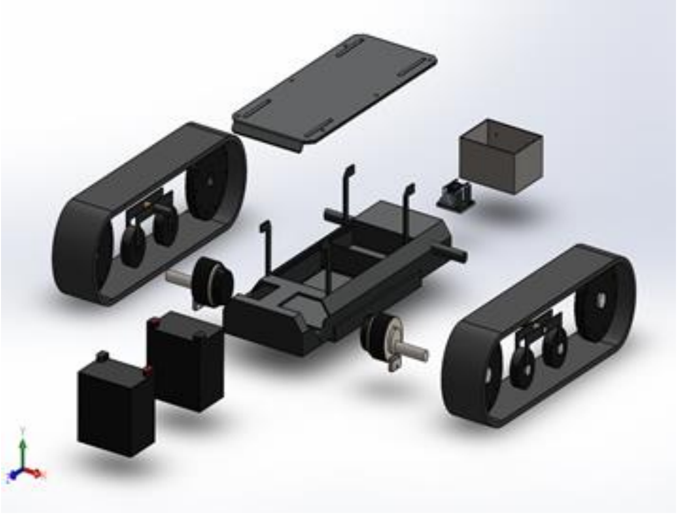


*Figure 7:*Exploded View

5 CONCLUSIONS

In this report we covered a list of requirements for our project along with methods for implementation of our proposed design. Our task is to reverse engineer and design a mobile explorer tracked robot with a budget of $1500.00. As part of our customer needs, we are tasked with creating a robot scaled off the original design that will meet much of the original robots' capabilities with a scale of 3:4. Our client tasked the team with manufacturing and designing this robot with a budget of $1500.00. With this budget we were able to secure the exact electronics components used in the original design including motors, speed controller receiver, transmitter and fused switch.

Our final solution is a two-motor remote control robot that will still be able to perform adequately compared to its bigger original design. This smaller alternative is lighter and faster due to the decreased weight and more powerful motors. Because of this the team expects performance added to this new design. The purpose of this project is to help aid in future classroom settings in classes such as ME 186, 286, 386W. Overall in the first semester the team was able to complete all the electronic portions of the design and conducted testing on failsafe procedures within the electronics system.

For next semester the team plans to focus on the implementation of a new chassis design that can be outsourced or made in our inhouse machine shop. The tacks will greatly influence the size of the robot so ordering this soon will allow the team more time to make updates and changes to the chassis design before final assembly.

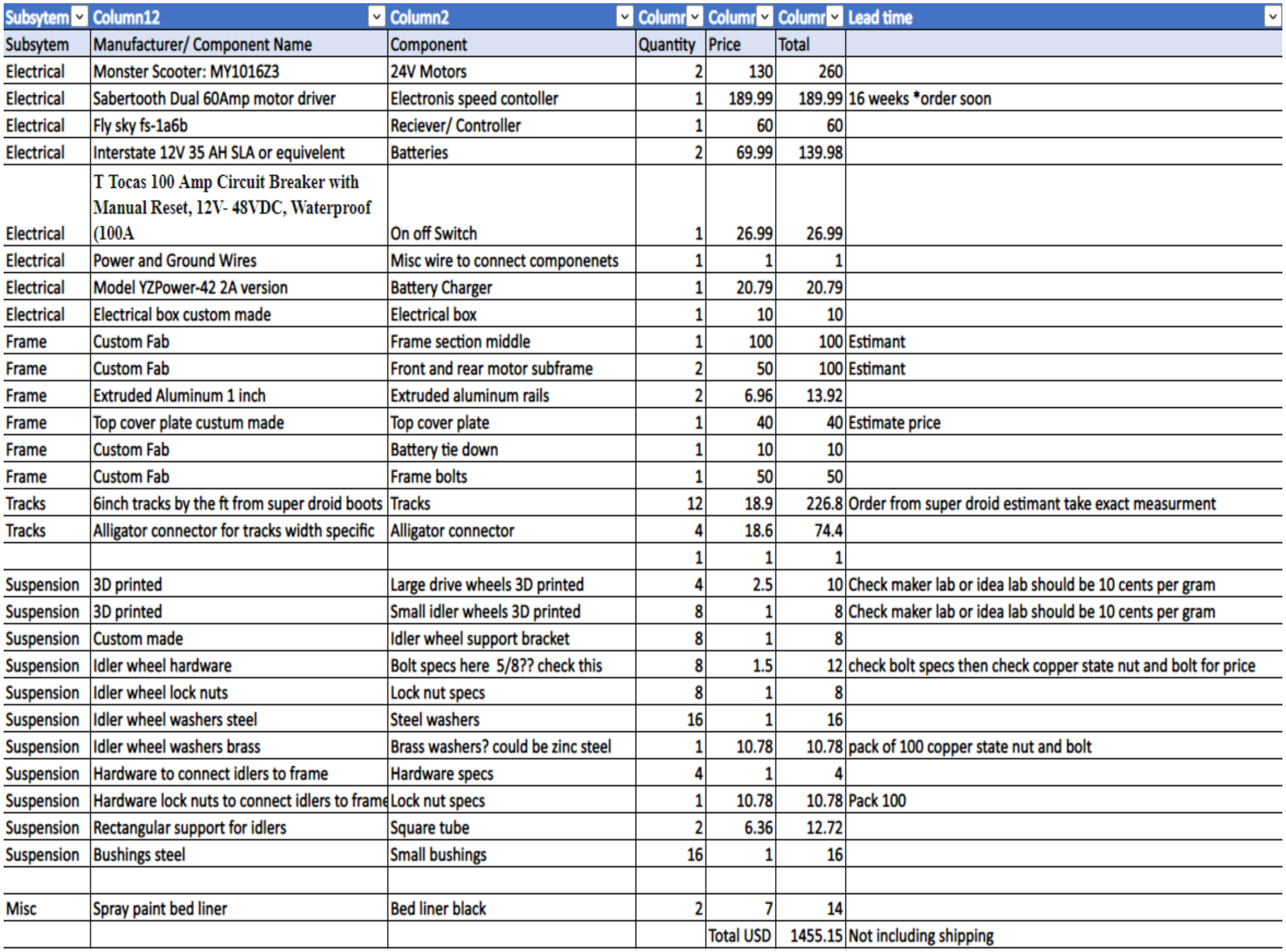
6 REFERENCES

[1] SuperDroid Robots, "GRT1000 heavy-duty tracked ATR Robot," *SuperDroid Robots*. [Website]. Available: https://www.superdroidrobots.com/Robots/robotic-kits-platforms/tracked-robots/product=3262. [Accessed: 31-Jan-2022].

[2] "Best 3D printer filament for 2022 – the ultimate guide," *All3DP*, 16-Feb-2022. [Online]. Available: https://all3dp.com/1/3d-printer-filament-types-3d-printing-3d-filament/. [Accessed: 04-Mar-2022].

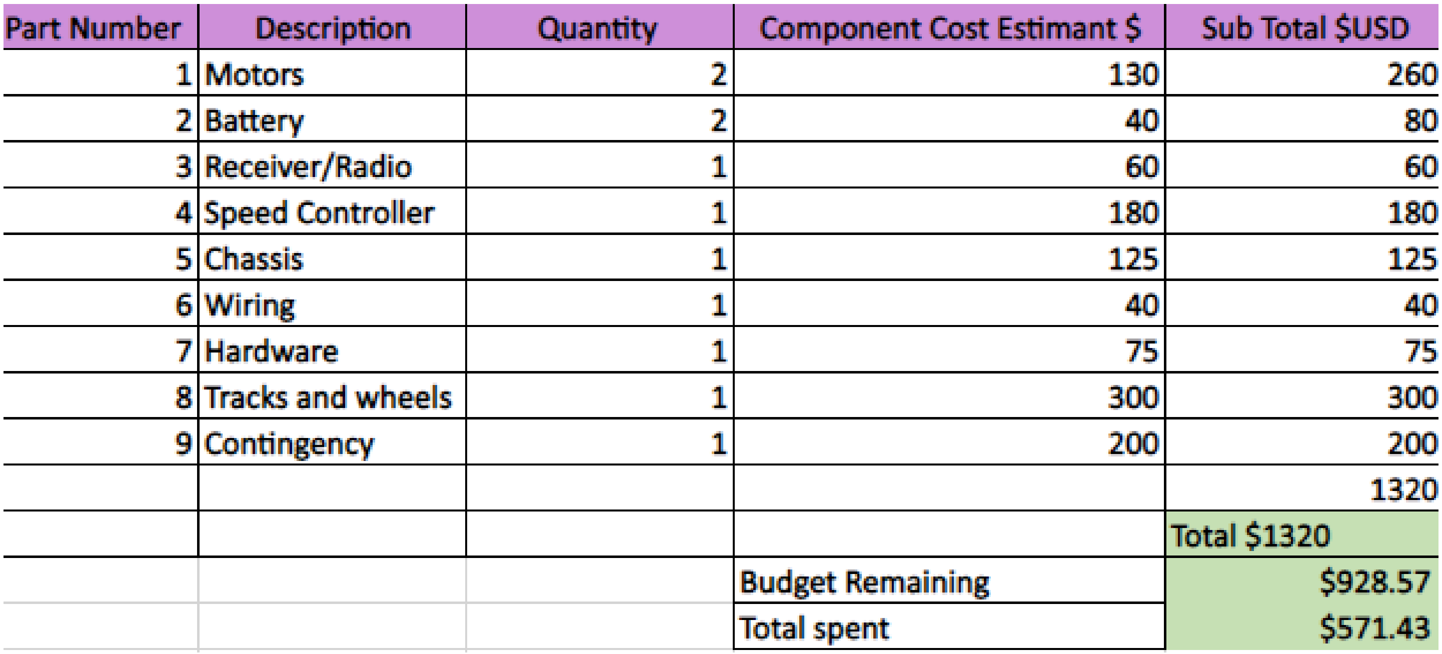
7 APPENDICES

7.1 Appendix A: Bill of Materials



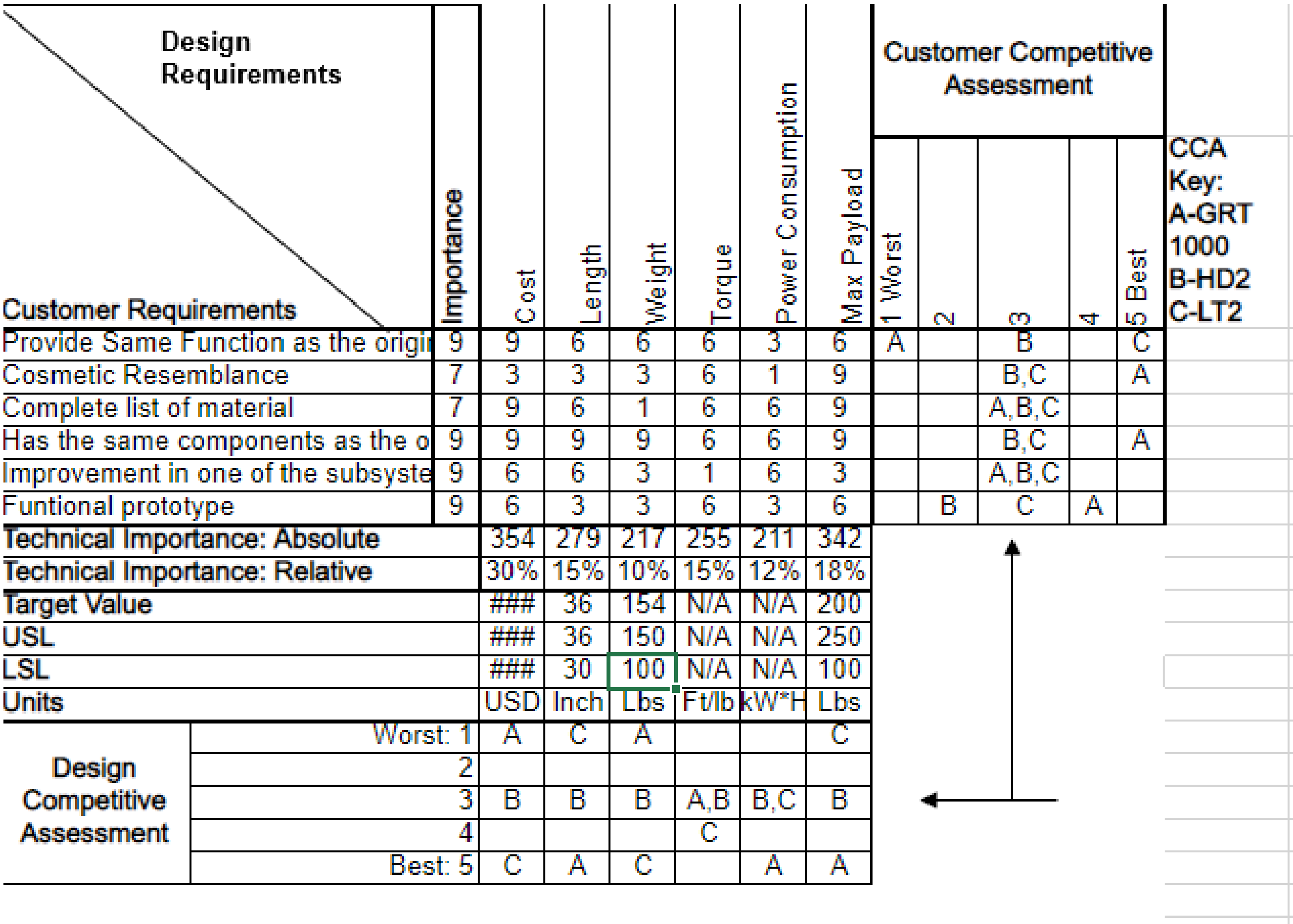
Subsytem	Column12	Column2	Columr	Columr	Columr	Lead time
Subsytem	Manufacturer/ Component Name	Component	Quantity	Price	Total	
Electrical	Monster Scooter: MY1016Z3	24V Motors	2	130	260	
Electrical	Sabertooth Dual 60Amp motor driver	Electronis speed contoller	1	189.99	189.99	16 weeks *order soon
Electrical	Fly sky fs-1a6b	Reciever/ Controller	1	60	60	
Electrical	Interstate 12V 35 AH SLA or equivelent	Batteries	2	69.99	139.98	
Electrical	T Tocas 100 Amp Circuit Breaker with Manual Reset, 12V- 48VDC, Waterproof (100A	On off Switch	1	26.99	26.99	
Electrical	Power and Ground Wires	Misc wire to connect componenets	1	1	1	
Electrical	Model YZPower-42 2A version	Battery Charger	1	20.79	20.79	
Electrical	Electrical box custom made	Electrical box	1	10	10	
Frame	Custom Fab	Frame section middle	1	100	100	Estimant
Frame	Custom Fab	Front and rear motor subframe	2	50	100	Estimant
Frame	Extruded Aluminum 1 inch	Extruded aluminum rails	2	6.96	13.92	
Frame	Top cover plate custum made	Top cover plate	1	40	40	Estimate price
Frame	Custom Fab	Battery tie down	1	10	10	
Frame	Custom Fab	Frame bolts	1	50	50	
Tracks	6inch tracks by the ft from super droid boots	Tracks	12	18.9	226.8	Order from super droid estimant take exact measurment
Tracks	Alligator connector for tracks width specific	Alligator connector	4	18.6	74.4	
			1	1	1	
Suspension	3D printed	Large drive wheels 3D printed	4	2.5	10	Check maker lab or idea lab should be 10 cents per gram
Suspension	3D printed	Small idler wheels 3D printed	8	1	8	Check maker lab or idea lab should be 10 cents per gram
Suspension	Custom made	Idler wheel support bracket	8	1	8	
Suspension	Idler wheel hardware	Bolt specs here 5/8?? check this	8	1.5	12	check bolt specs then check copper state nut and bolt for price
Suspension	Idler wheel lock nuts	Lock nut specs	8	1	8	
Suspension	Idler wheel washers steel	Steel washers	16	1	16	
Suspension	Idler wheel washers brass	Brass washers? could be zinc steel	1	10.78	10.78	pack of 100 copper state nut and bolt
Suspension	Hardware to connect idlers to frame	Hardware specs	4	1	4	
Suspension	Hardware lock nuts to connect idlers to frame	Lock nut specs	1	10.78	10.78	Pack 100
Suspension	Rectangular support for idlers	Square tube	2	6.36	12.72	
Suspension	Bushings steel	Small bushings	16	1	16	
Misc	Spray paint bed liner	Bed liner black	2	7	14	
				Total USD	1455.15	Not including shipping

7.2 Appendix B : Budget Spent on Prototype



Part Number	Description	Quantity	Component Cost Estimant $	Sub Total $USD
1	Motors	2	130	260
2	Battery	2	40	80
3	Receiver/Radio	1	60	60
4	Speed Controller	1	180	180
5	Chassis	1	125	125
6	Wiring	1	40	40
7	Hardware	1	75	75
8	Tracks and wheels	1	300	300
9	Contingency	1	200	200
				1320
				Total $1320
			Budget Remaining	$928.57
			Total spent	$571.43

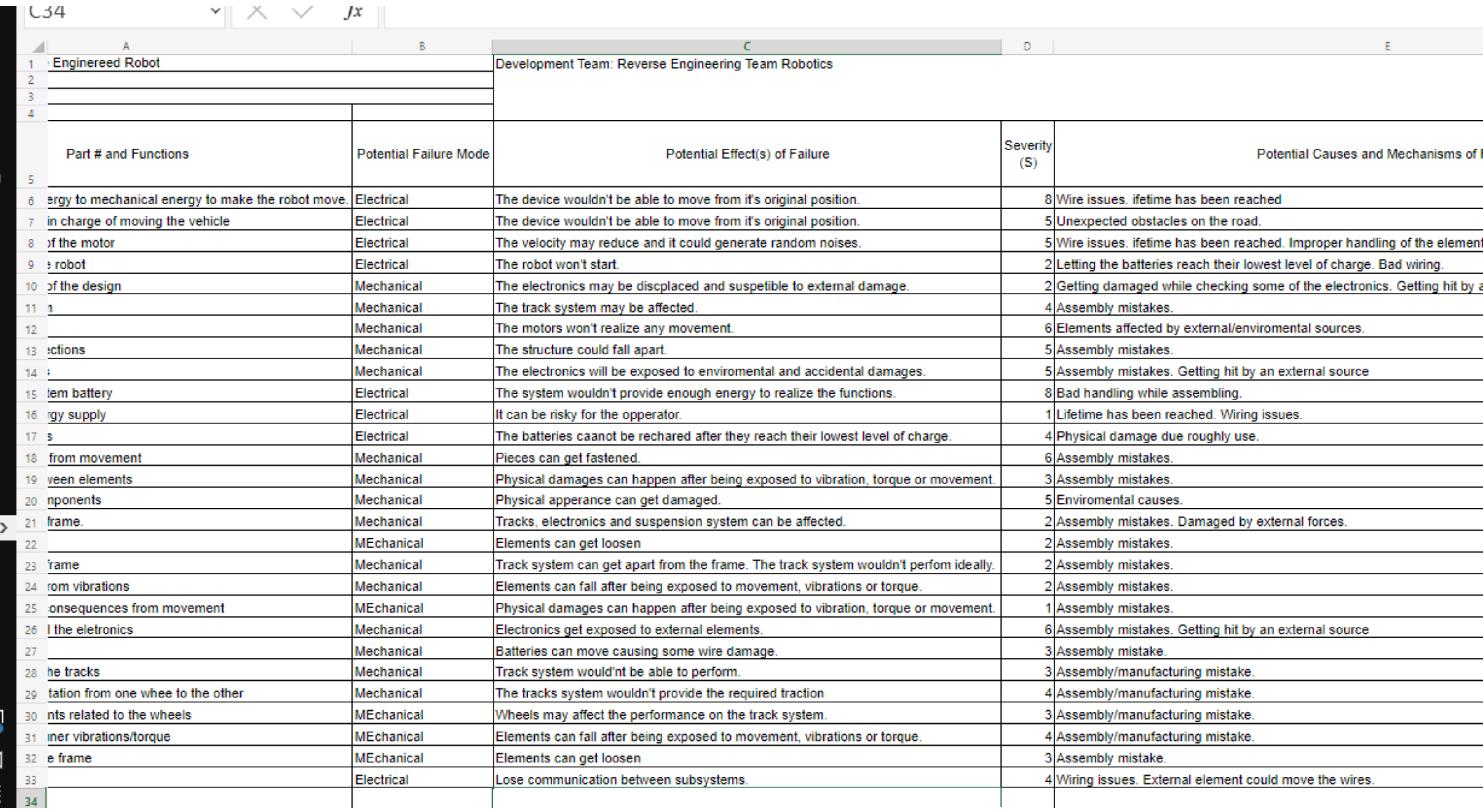
7.3 Appendix C: HoQ



Design Requirements / Customer Requirements	Importance	Cost	Length	Weight	Torque	Power Consumption	Max Payload	Customer Competitive Assessment: 1 Worst	2	3	4	5 Best
Provide Same Function as the origi	9	9	6	6	6	3	6	A		B		C
Cosmetic Resemblance	7	3	3	3	6	1	9			B,C		A
Complete list of material	7	9	6	1	6	6	9			A,B,C		
Has the same components as the o	9	9	9	9	6	6	9			B,C		A
Improvement in one of the subsyste	9	6	6	3	1	6	3			A,B,C		
Funtional prototype	9	6	3	3	6	3	6		B	C	A	
Technical Importance: Absolute		354	279	217	255	211	342					
Technical Importance: Relative		30%	15%	10%	15%	12%	18%					
Target Value		###	36	154	N/A	N/A	200					
USL		###	36	150	N/A	N/A	250					
LSL		###	30	100	N/A	N/A	100					
Units		USD	Inch	Lbs	Ft/lb	kW*H	Lbs					
Design Competitive Assessment	Worst: 1	A	C	A			C					
	2											
	3	B	B	B	A,B	B,C	B					
	4				C							
	Best: 5	C	A	C		A	A					

CCA Key:
A-GRT 1000
B-HD2
C-LT2

APPENDIX 7.4. FMEA



	A	B	C	D	E
1	Engineereed Robot		Development Team: Reverse Engineering Team Robotics		
2					
3					
4					
5	Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Severity (S)	Potential Causes and Mechanisms of
6	ergy to mechanical energy to make the robot move.	Electrical	The device wouldn't be able to move from it's original position.	8	Wire issues. ifetime has been reached
7	in charge of moving the vehicle	Electrical	The device wouldn't be able to move from it's original position.	5	Unexpected obstacles on the road.
8	f the motor	Electrical	The velocity may reduce and it could generate random noises.	5	Wire issues. ifetime has been reached. Improper handling of the elemen
9	robot	Electrical	The robot won't start.	2	Letting the batteries reach their lowest level of charge. Bad wiring.
10	f the design	Mechanical	The electronics may be discplaced and suspetible to external damage.	2	Getting damaged while checking some of the electronics. Getting hit by a
11	n	Mechanical	The track system may be affected.	4	Assembly mistakes.
12		Mechanical	The motors won't realize any movement.	6	Elements affected by external/enviromental sources.
13	ctions	Mechanical	The structure could fall apart.	5	Assembly mistakes.
14		Mechanical	The electronics will be exposed to enviromental and accidental damages.	5	Assembly mistakes. Getting hit by an external source
15	tem battery	Electrical	The system wouldn't provide enough energy to realize the functions.	8	Bad handling while assembling.
16	gy supply	Electrical	It can be risky for the opperator.	1	Lifetime has been reached. Wiring issues.
17	s	Electrical	The batteries caanot be rechared after they reach their lowest level of charge.	4	Physical damage due roughly use.
18	from movement	Mechanical	Pieces can get fastened.	6	Assembly mistakes.
19	veen elements	Mechanical	Physical damages can happen after being exposed to vibration, torque or movement.	3	Assembly mistakes.
20	nponents	Mechanical	Physical apperance can get damaged.	5	Enviromental causes.
21	frame.	Mechanical	Tracks, electronics and suspension system can be affected.	2	Assembly mistakes. Damaged by external forces.
22		MEchanical	Elements can get loosen	2	Assembly mistakes.
23	rame	Mechanical	Track system can get apart from the frame. The track system wouldn't perfom ideally.	2	Assembly mistakes.
24	rom vibrations	Mechanical	Elements can fall after being exposed to movement, vibrations or torque.	2	Assembly mistakes.
25	onsequences from movement	MEchanical	Physical damages can happen after being exposed to vibration, torque or movement.	1	Assembly mistakes.
26	the eletronics	Mechanical	Electronics get exposed to external elements.	6	Assembly mistakes. Getting hit by an external source
27		Mechanical	Batteries can move causing some wire damage.	3	Assembly mistake.
28	he tracks	Mechanical	Track system would'nt be able to perform.	3	Assembly/manufacturing mistake.
29	tation from one whee to the other	Mechanical	The tracks system wouldn't provide the required traction	4	Assembly/manufacturing mistake.
30	nts related to the wheels	MEchanical	Wheels may affect the performance on the track system.	3	Assembly/manufacturing mistake.
31	ner vibrations/torque	MEchanical	Elements can fall after being exposed to movement, vibrations or torque.	4	Assembly/manufacturing mistake.
32	e frame	MEchanical	Elements can get loosen	3	Assembly mistake.
33		Electrical	Lose communication between subsystems.	4	Wiring issues. External element could move the wires.
34					