ENGR 2620

Integration

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Wall-E Project Final Report

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Report Grade: ____________

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Executive Summary

BioComp, LL.C needs a small robot to work in the company's cleanroom and has different teams competing for the contract to manufacture and maintain the robot. One of the main requirements for the small robot was that the system must be an autonomous vehicle. The system should accomplish the three tasks presented by the client. The first task that needed to be completed by the vehicle was the pickup-and-place task. The second task that needed to be accomplished by the vehicle was the carry/push/pull task. The third task that needed to be accomplished by the vehicle was the obstacle avoidance task. Not only did the vehicle need to accomplish the three separate tasks but also needed to fit within the client's constraints. The maximum length of the vehicle was 530mm. On the other hand, the maximum width of the vehicle was 280mm. To add on, the system development has constraints of its own. To be more specific, the system is only constrained to the components and devices in Figure 4.

Given the constraints of the system, a project management plan was created in order to efficiently utilize the nine weeks given for the project. With that four different conceptual designs were created. To be able to evaluate the feasibility of each design, a design matrix was created to pick the final design of the system. Once the design was finalized, the design was built. The design contained mainly three special features. The first feature was the wheel orientation which would maximize the stability of the vehicle as well as its overall movement. The second feature was the stacked grid design which would help with the organization of the Teensy and wires of the system. To add on, the stacked grid design also helped shorten the gripper arm of the system which in the end created a more effective pickup and place system. The third feature was the addition of IR sensors to the system in order to prevent any damage to the objects being picked up or dropped off by the gripper.

With the prototype completely built, the system was tested on the field provided by the clients. In terms of the obstacle avoidance task, the system was able to stay within the course boundaries. To add on, the system was also able to detect a wall and avoid touching the wall. The system was also able to find and go through the 1st and 2nd openings in the wall. At the end of the task, the vehicle was also able to stop at the finish line of the course. In terms of the pickup-and-place task, the system was able to pick up the payload and determine the size of the payload. To add on, the system was also able to successfully place and determine the correct placement pedestal based on the payload size. Finally, in terms of the carry/push/pull task the carry threshold was achieved, and its measurements can be found below in the appendix.

1. Introduction

The main goal of the project was to design a small robot to work in BioComp, LL.C's cleanroom. More specifically, the main goal was to design and build an autonomous vehicle that can accomplish the following three tasks. The first task was that the vehicle shall pickup-and-place. Specifically, the vehicle shall start from a fixed location and shall approach a 'pickup' platform. The client will provide a large or small, red or blue colored box on the pickup platforms. The small robot shall pick up the box and based on the color of the box, the small robot shall find and follow the colored path to the 'placement' platforms. Based on the six and color of the box, the vehicle shall place the cube on the appropriate platform. The cube cannot be damaged throughout the process. The layout of the pickup and place field is shown in Figure 1. The pickup and place platforms are shown in Figure 2. The second task was that the vehicle shall carry and push or pull. The small robot shall start at the bottom of an 18.5-degree ramp and shall carry and push or pull an object to the top of the ramp. The vehicle cannot lose or drop the object and the vehicle cannot tip over. The vehicle and the object must stay on the ramp. The task will be evaluated based on the amount of weight the vehicle can carry and push or pull as well as the angle of the ramp. The third task was that the vehicle shall move with obstacle avoidance. The vehicle shall start from one of three fixed positions and shall navigate across a field with obstacles and stop at the 'finish line' at the end of the field in the fastest possible time. The vehicle is required to stay within the bounds of the field and avoid the walls. Touching or knocking down a wall results in a time penalty.

The following report outlines the design and development process of the autonomous vehicle. The design and development process was spread over the course of nine weeks. The report starts off with the project management plan and system requirements. The project management plan highlights the critical events during the development of the system. The system requirements portion of the report details how the client will use the system and goes through the client's requirements and other features desired by the client. The report then goes into the concept of operations and concept design. The concept of operations describes how the operator will use the system and also includes how the system is to be supported. The concept design section goes through design ideas that accomplish the client's objectives. After the concept designs, the report goes into the feasibility analysis of the system and goes into the system risk management of the system. The feasibility analysis section compares and contrasts the design concepts and presents a design matrix. The system risk management section goes through the major sources of risk in the system and the plans to mitigate those risks. The end of the report outlines the design of the system, system test and verification, and the system analysis and system performance metrics. The detailed design section of the report describes the design of the system. On the other hand, the system test and verification section of the report goes through the testing results and the evaluation of the key performance criteria. Finally, the system analysis and system performance metrics quantify and analyze the performance and behavior of the system.

2. Project Management Plan

The following Gant chart briefly explains the development of the system. Specifically, the chart depicts the different phases of development for the system and who was assigned to a certain task. To add on, the chart also demonstrates the progress of those tasks and includes the project timeline. The first phase of the project consisted of organizing the team. The most important events that occurred during the first phase were setting up the file system and beginning documentation. The first phase of the project took place during the first week of the quarter. The second phase of the project consisted of developing the early concepts of the system. The most important events that occurred during the second phase were designing different ideas for the system, creating a design matrix, and finalizing the system for the next phase. The second phase of the project took place during the second week of the quarter.

The next phase of the project consisted of prototyping. Some of the most important events that occurred during the third phase was finalizing the subsystem components, manufacturing subsystems, developing software for controlling the vehicle's movements, integrating electronic components, attaching all mechanical systems, and finalizing the system changes. The third phase of the project took place during the third week of the quarter to the seventh week of the quarter. The next phase of the project consisted of system verification. The most important events that occurred during the fourth phase were the verification and validation of the function requirement, the operational and user requirement, the physical requirement, and the safety requirement. The fourth phase of the project took place during the eighth week of the quarter. Finally, the last phase of the project consisted of the finalization of the system. The most important events that occurred during the final phase were the finalization of the mechanical system, the electrical system, the software system, the documentation, and the presentation of the final product. The last phase of the project took place during the ninth week of the quarter. For more detailed information, please reference the Gantt chart located below.

Group 5

Project Start: 3/20/23

Winter Quarter 1 2 3 4 5 6 7 8 9 10 F — Spring Quarter 1 2 3 4 5 6 7 8 9 10 F

Task		Assigned To	Progress (%)
Phase 1 : Team Organization			
Task 1.1 :	Organize team structure	AEPR	100%
Task 1.2 :	Setup filesystem	A	100%
Task 1.3 :	Start documentation	A	100%
Phase 2 : Early Concepts			
Task 2.1 :	Design ideas for the outershell of Dave	AEPR	100%
Task 2.2 :	Outershell proof of concepts	R	100%
Task 2.3 :	On-site testing	E	100%
Task 2.4 :	Electronic selections	ER	100%
Task 2.5 :	Design ideas for system	AEPR	100%
Task 2.7 :	Basic CAD drawings of designs	PR	100%
Task 2.6 :	Process the data of proof of concept Dave	AEPR	100%
Task 2.8 :	Design matrix and selection for system components	AEPR	100%
Task 2.9 :	Electrical schematics	R	100%
Task 2.10 :	Heat distribution concepts	P	100%
Task 2.11 :	Finalize system concept for prototyping phase	AEPR	100%
Phase 3 : Prototyping			
Task 3.1 :	Preliminary simulation of Dave's movements and sensors	ER	100%
Task 3.2 :	CAD of prototype chassis/ drive train	PR	100%
Task 3.3 :	Theoritical subsystem analysis	ER	100%
Task 3.4 :	Finalization simulation	ER	100%
Task 3.5 :	Finalize subsystem components	AEPR	100%
Task 3.6 :	CAD cable management for finalized system concept	ER	100%
Task 3.7 :	Purchase electronic and mechanical components for subsystems	AEPR	100%
Task 3.8 :	Manufacture subsystems	EPR	100%
Task 3.9 :	Analysis of power distribution of system	R	100%
Task 3.10 :	Battery selection	ER	100%
Task 3.11 :	Build chassis	AEPR	100%
Task 3.12 :	Analysis of drivetrain	P	100%
Task 3.13 :	Software for controlling Dave's movements	EPR	100%
Task 3.14 :	Mechanical safety verification across system	AP	100%
Task 3.15 :	Electrical safety verification across system	ER	100%
Task 3.16 :	Software on user interface	EPR	100%
Task 3.17 :	Interface electronic components with appropriate subsystems	EPR	100%
Task 3.18 :	Finalize Dave Securement Candidate	A	100%
Task 3.19 :	Dave Securement Site Analysis	ER	100%
Task 3.20 :	Manufacturing of Dave Securement Site	EP	100%
Task 3.21 :	Finalize and Build Electronics in Box	EPR	100%
Task 3.22 :	Finalize Battery	R	100%
Task 3.23 :	Manufacture Battery Securement	A	100%
Task 3.24 :	Finalize and Attach All Mechanical Subsystems	AR	100%
Task 3.25 :	Build Chassis	A	100%
Task 3.26 :	Integrate electronic components with chassis sites	EPR	100%
Task 3.27 :	Finalizing system changes	EPR	100%
Phase 4 : Verification			
Task 4.1 :	Verify and validate function requirement	EPR	90%
Task 4.2 :	Verify and validate performance requirement	EPR	90%
Task 4.3 :	Verify and validate operational and user requirement	EPR	90%
Task 4.4 :	Verify and validate enviromental requirement	EPR	100%
Task 4.5 :	Verify and validate physical requirement	EPR	100%
Task 4.6 :	Verify and validate safety requirement	EPR	90%
Phase 5 : Finalization			
Task 5.1 :	Finish mechanical system	ER	100%
Task 5.2 :	Finish electrical	ER	100%
Task 5.3 :	Finish software	EPR	100%
Task 5.4 :	Finalize verification and validation documentation	A	80%
Task 5.5 :	Finish documentation	A	100%
Task 5.6 :	Present final product	AEPR	90%

Figure 1 - Gant Chart

3. System Requirements

The following subsections detail the system requirements.

3.1 The system shall be autonomous

The system should be capable of sensing its environment and operate without human involvement. The system should be able to pick up and place objects on its own. The system should be able to carry and push or pull objects up the ramp on its own. The system should sense the obstacles and avoid the obstacles without any human involvement.

3.2 The system shall pickup-and-place

3.2.1 The system shall approach a ‘pickup’ platform

The system will start from a fixed location and approach the area of the platform. Once in the area, the system should be able to detect the platform with the object on top of it.

3.2.2 The system shall pick up the box

The system should be able to detect the box on the platform. The gripper should have a sensor that will indicate at what point the gripper should stop before damaging the box. Once the system has picked up the box, the system should backup away from the platform without dropping the box.

3.2.2.1 The system shall find the colored path

The system should be able to detect the select colored path after it backs up from the platform and begin following the path.

3.2.2.2 The system shall follow the colored path to the ‘placement’ platforms

The system should detect the color of the box and navigate towards the red or blue path after it follows the green path.

3.2.2.3 The system shall place the box on the appropriate platform

The system should continue to follow the path until the other end of the field. At the other end of the field, the system will approach and detect the ‘placement’ platform. Once the platform is detected, the system should release the box onto the platform.

3.2.2.4 The system shall not damage the box

The box is fragile and cannot be damaged which was requested by the client.

3.3 The system shall carry + (push or pull)

3.3.1.1 The system shall carry an object to the top of the ramp

The system should be designed to carry a good amount of weight.

3.3.1.2 The system shall either push or pull an object to the top of the ramp

The system should be designed to push or pull weight without being affected by the weight.

3.3.1.3 The system shall not drop the weight

The system should be designed to keep the weight on the vehicle as the system goes up the ramp at different angles.

3.3.1.4 The system shall not tip over

The system should be designed to remain steady without falling over to not damage any of the system's components.

3.3.1.5 The system and object shall stay on the ramp

The system should have an algorithm that will allow the vehicle to stop at a certain point before the vehicle drives off the ramp. Staying on the ramp will ensure the preservation of the system's components.

3.4 The system shall move with obstacle avoidance

The system requires obstacle avoidance because the system may need to maneuver around other objects in the company's cleanroom.

3.4.1.1 The system shall start at a fixed position

The system should start at a fixed position to be able to function autonomously.

3.4.1.2 The system shall navigate across a field with obstacles

The system should be able to avoid objects in its path that don't correspond to the pickup and placement platforms.

3.4.1.3 The system shall stop at the 'finish' line

The system should stop at the 'finish' line to indicate that the system has completed one of the tasks.

3.4.1.4 The system shall stay within the field bounds

The system should stay within the designated location.

3.4.1.5 The system shall not touch or knock down a wall

The system should maneuver around other objects without running into them to be able to keep the system intact as well as the other objects in the field.

3.5 The system shall follow the design constraints

3.5.1.1 The system shall measure within the max length (530mm)

The client specified the max length of the system.

3.5.1.2 The system shall measure within the max width (280mm)

The client specified the max width of the system.

3.5.1.3 The system shall only contain the components and devices found in Tables 5-6

The system should only contain the components and devices in Tables 5-6 (found below in the appendix) in order to comply with one of the client's constraints.

4. CONOPs (Concept of Operations)

The vehicle must first achieve all system requirements. The vehicle must not exceed a size of 21 inches in length and a width of 11 inches. The vehicle at rest must fit inside this size requirement, failing to meet the size requirements results in a possible failure of the system.

The vehicle the team built must then complete three separate tasks. The first task is to pick up an object, follow a path, and place the object on the correct pedestal. The second task is to be able to carry and push or pull weighted objects up a ramp at varying angles. The third task is to have the vehicle make it to the opposite side of an obstacle course without colliding with any obstacles. Tasks one and three are evaluated based on the completion time, while task two is evaluated based off the maximum amount of weight a vehicle can take up the ramp.

4.1 Task 1 - Pickup and Place

For this task, the object must pick up a box, follow the correct path, and place the box down without damaging the box itself. To begin, the user places the robot in front of the first pedestal. The user then turns the battery on, after which, the vehicle then approaches the pedestal until it senses it, and then stops in a position where the box can be grabbed. The system then triggers the gripper to close. In this stage, the system is able to detect the size and color of the box. The system can detect either a big box (2"x 2"x 2") or a small box (1" x 2"x 2"). The system can also detect if the box is red or blue, creating 4 different possible scenarios. Each combination corresponds to its own pedestal on the opposite end of the map, where the box will be placed. The vehicle can autonomously follow the path based on the size and color of the box that is in its possession. The template map can be seen in the figure below.

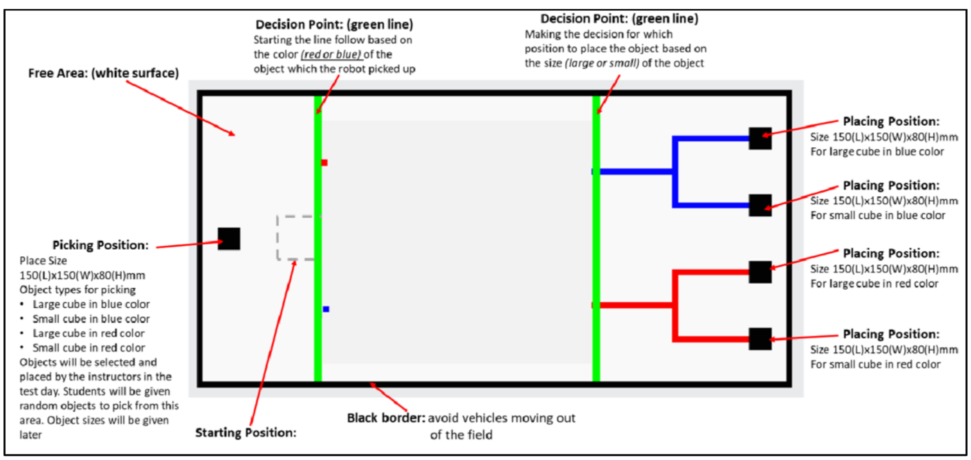


Figure 2 - Template map of task 1.

After picking up the box, the vehicle makes a 180 degree turn and then moves forward until it reaches the first decision point. The vehicle then moves to the correct path based on the type of box in it's possession. The vehicle then follows the path in the center until it reaches the second decision point, where the vehicle then prepares to turn based on the size of the box. After following the correct path, the vehicle will then gently place the box down after approaching the pedestal. After, the vehicle will then stop, ending task 1.

4.2 Task 2- Carry/ Push/ Pull

This task tests how much weight the vehicle can carry up the ramp, and either push or pull up. The vehicle is initially tested at 18.5 degrees and incremented upwards to 45 degrees. Located on the top grid plate is a location to carry the weight. Weights are able to be placed inside until the vehicle can no longer move upward. The vehicle is tested to go up at varying weights and varying angles.

For the second part of this task, the vehicle must push or pull weight up the ramp. Our group decided to push the weight, as it better served the balance of the vehicle. Weight was placed in front of the vehicle and was pushed upward until the vehicle could no longer move up the ramp.

4.3 Task 3- Move with Obstacle Avoidance

In this task the vehicle must begin on one of three fixed positions. The vehicle must then navigate through a field, avoid all obstacles and reach the opposite end. The vehicle must also stay inside the bounds and not leave the map. The obstacles in task are three walls, the walls have the ability to change positions before the vehicle is turned on, and the vehicle must prove that it is able to reach the end in any configuration of walls. The field boundary is white, the color of the field is black, and the finish line is green. The wall placement is always parallel to the finish line and has a 600 mm gap between each wall. The configuration of walls always consists of two long walls, forcing the vehicle to move far right or far left, and a combination of two small walls, forcing the vehicle to the middle. The walls will always consist of a left, right and middle opening, but the order of the openings is rearranged before every test.

For our design, the vehicle has the ability to be placed in any starting location. The vehicle will begin at the line, and when the battery is turned on the vehicle will begin moving forward. The vehicle will then move forward until the IR sensor detects an obstacle, the vehicle will then move right until an opening is found, once an opening is found the vehicle will then move forward until another obstacle is found. The vehicle will continue to move right until reaching the white border, the vehicle will then begin moving left, and repeating this motion until an opening is found, if no opening is found the vehicle will continue left and right motion until the vehicle turned off.

The vehicle completes this task when it reaches the green finish line. As soon as the green line is sensed, the vehicle will then stop motion. The constant left and right scanning allows for the vehicle to reach the end under any wall configuration and starting position. In this task the vehicle is not only rated on its ability to reach the finish line, but also the time that the vehicle is able to complete the task.

5. Conceptual Design

Each member of the team created a conceptual design of the vehicle with the knowledge of the parts that were available for usage and the CONOPs of the vehicle. Individual concepts were then presented to the group and a Decision Matrix was used to decide what design would be used for prototyping. Each member created unique designs, as the prototyping process was in progress the team found that certain aspects of the different vehicles would work better for the final design. The team created the following designs: square grid orientation, single grid, long grid, and stacked orientation. Each design will be looked at in depth in the following sections.

5.1 Square Grid Orientation

This design concept utilizes the two grid plates in which the plates are overlayed in a squared position. The wheels are placed on each side of the vehicle. The design contains a gripper arm positioned in the center of the vehicle. The design can be seen below in figure 3:

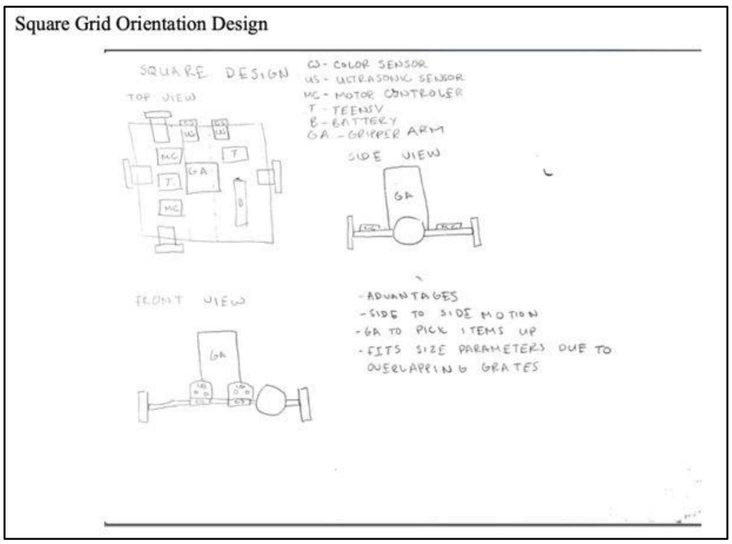


Figure 3 - Square Grid Orientation

The design contains two 3D printed sensors mounts which would hold one ultrasonic and one color sensor each. This will allow the concept to complete the line following aspect of task one, obstacle avoidance of task three. The gripper arm contains the full assembly in the center, which would complete the pickup and put down of task one. Motor controller, bread boards and the battery all have space on the vehicle and could be moved in order to maximize spacing and reduce wiring.

This design fits all the requirements needed. The advantages seen in this particular design were the amount of surface that was able to be utilized, and the orientation of the wheels with a combination of Omni-wheels allows for easy motion in all directions.

5.2 Single Grid

The single grid design utilizes one grid. The wheels are oriented on the sides of the vehicle, with a gripper arm attached to the front of the vehicle. The concept can be seen in figure 4:

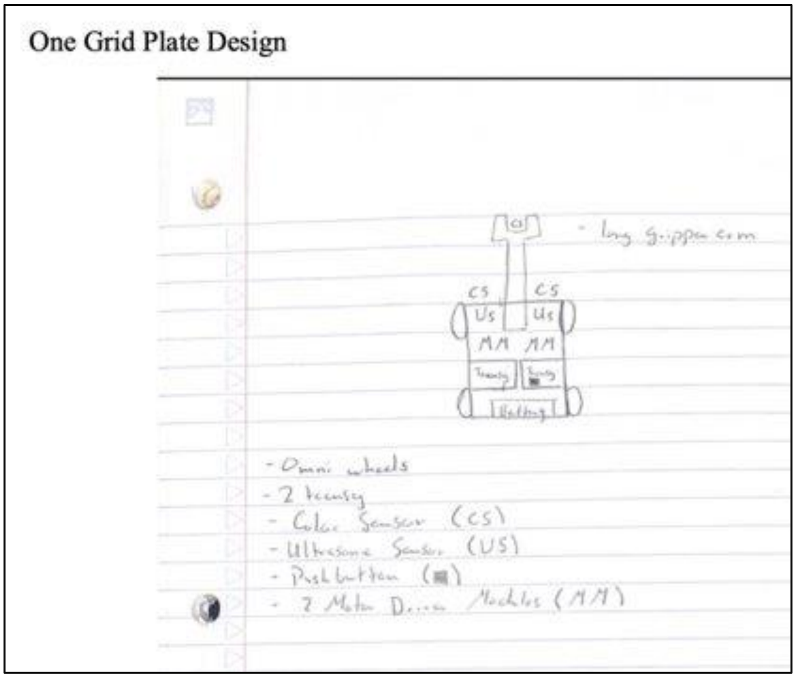


Figure 4- Single Grid design

The single grid also uses the two 3D printed mounts containing one ultrasonic and one color sensor each. This will allow the concept to complete the line following aspect of task one, obstacle avoidance of task three. The gripper arm in the front allows for the completion of task one, with the motor controller, breadboards and battery located on the back end of the vehicle.

This design fits all the requirements needed. The advantages seen in this design is the small size would add to the maneuverability of the vehicle paired with all four motors. This design had potential of push/pull/carry a lot of weight due to the small size and the power of all four motors in the same direction.

5.3 Long Grid

This design overlays one plate on the end of the other plate creating a long grid. The wheels are placed on the sides of the vehicle. The concept can be seen in figure 5:

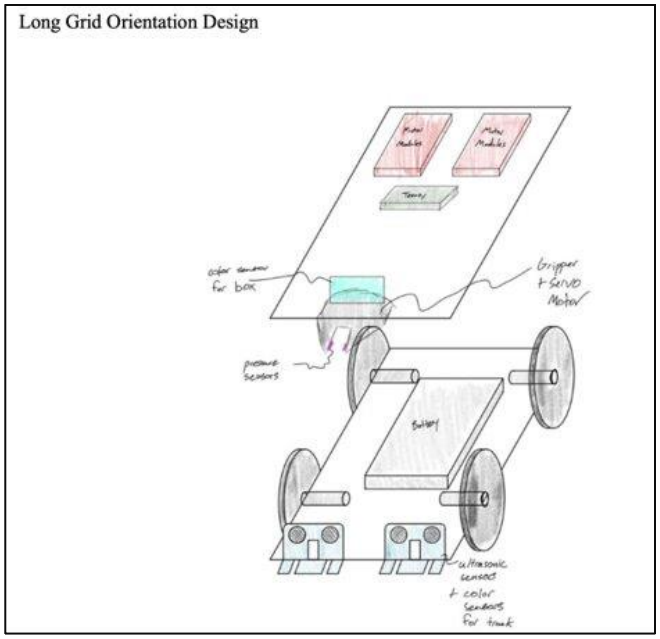


Figure 5- Long grid orientation.

This design is similar to the single grid design with the added plate in the back of the vehicle for extra room for the motor controllers, breadboards and the battery. It utilizes all the same components as in the single grid design, but allows for much more room for the needed components.

The design has the capability to perform tasks one and three since the design does follow the single grid plate. The advantage of this design is that it allows for more space, which would allow much better wire organization room for extra components.

5.4 Stacked Grid

In this design the grids are layered on top of one another. The wheels are located on each side of the vehicle. The gripper is located on the top grid plate without an arm. The concept can be seen below in figure 6:

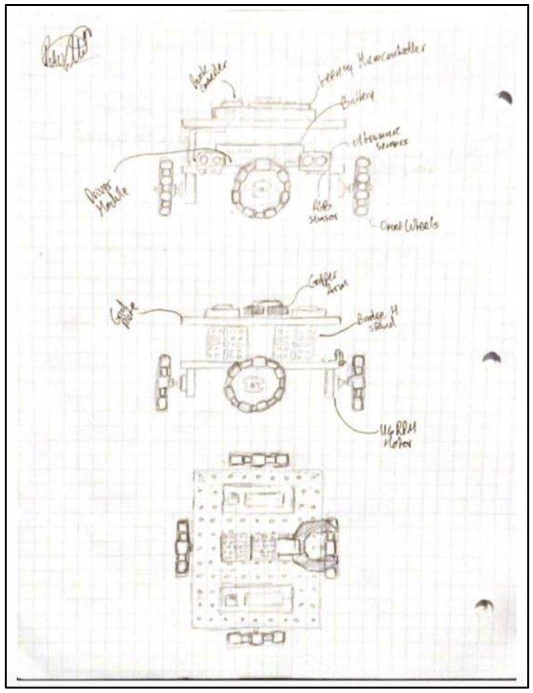


Figure 6- Stacked grid design.

In this design contains two of the 3D printed mounts, holding one ultrasonic and one color sensor each. This allows for the line following task and obstacle avoidance to be completed. It was found that the height of the stacked grid plates make the gripper a perfect height for the pedestal that the box would be placed on for task one, so it was not necessary for a full arm assembly. The motor controllers and the battery sit on the lower plate, allowing for tucked wire look.

This design meets all the requirements. One of the advantages of this design is the maneuverability of the design due to the usage of the Omni-wheels. Another advantage is with a gripper and no arm, it frees a lot of space along the top of the vehicle. The design creates a lot of open area for the needed components of the vehicle.

5.5 Feasibility Analysis: Decision Matrix and Final Design Recommendation

In order to choose a design to begin the prototyping process the team created a design matrix, in which each vehicle was rated individually in five distinct categories, the total rating was then averaged and chose the highest rated vehicle. The categories that each vehicle was rated in were feasibility, scalability, efficiency, distinctiveness, and hardware management. Each category was rated on a scale of one through four, and the outcome can be seen in figure 7 below

Raul	(Feasibility)*3	(Scalibility)*2	(Efficiency)*4	(Distinctivness)*1	(Hardware Management)*5	Total
Square Grid Orientation	3	3	3	2	3	44
Stacked Grids	2	2	4	4	4	50
Long Grid Orientation	1	1	2	3	1	21
One Grid Plate	4	4	1	1	2	35
Phillip	(Feasibility)*3	(Scalibility)*2	(Efficiency)*4	(Distinctivness)*1	(Hardware Management)*5	Total
Square Grid Orientation	4	2	3	3	3	46
Stacked Grids	3	3	4	4	3	50
Long Grid Orientation	1	2	1	4	2	25
One Grid Plate	1	2	3	1	1	25
Ana	(Feasibility)*3	(Scalibility)*2	(Efficiency)*4	(Distinctivness)*1	(Hardware Management)*5	Total
Square Grid Orientation	3	3	3	2	3	44
Stacked Grids	3	2	4	4	3	48
Long Grid Orientation	1	2	2	4	1	24
One Grid Plate	2	3	1	1	2	27
Evan	(Feasibility)*3	(Scalibility)*2	(Efficiency)*4	(Distinctivness)*1	(Hardware Management)*5	Total
Square Grid Orientation	2	2	3	4	3	41
Stacked Grids	1	4	1	3	4	38
Long Grid Orientation	3	3	2	2	2	35
One Grid Plate	4	1	4	1	1	36
Total						
Square Grid Orientation	175					
Stacked Grids	186					
Long Grid Orientation	105					
One Grid Plate	123					

Figure 7 - Design Matrix.

Feasibility covers how easy it would be to complete the tasks at hand. This means, as the vehicle is performing the tasks, if there are components of the design that may prohibit or cause issues with the functionality of the vehicle. As seen in the design matrix, the single and stack grid orientation scored high in the feasibility sections, having a small sized vehicle allows to perform tasks much easier than the larger configurations.

Scalability covers the ability to change the vehicle as needed. As the vehicle progresses through the prototyping phase, the group understood that some change may be needed. This category covers the vehicle's ability to move components around and switch configurations as needed. Certain designs offer very limited space, or only allow components to be placed in a certain position, this would cause the design to be rated low in this category.

Efficiency covers the speed that the design is able to complete the tasks at hand. For this section the group scored the stacked grid design to be most efficient in completing all three tasks. The ability to move in any direction at a given time means the ability to complete the obstacle avoidance in a timely manner, and the gripper configuration allows for less moving parts scoring the vehicle highest in this section. The faster the team believed the vehicle can complete the task, the higher of a rating that the vehicle received.

Distinctiveness rates the uniqueness of the design as compared to designs that we had seen from other groups. The more distinct that the configuration looked the higher of a rating that the design received, in other words the less the design looked like other groups the higher of a rating it had received.

Hardware management covers the ability to house all the given components that are needed, but also the ability to organize and tuck away wiring. Since one of the components of this project is the look of the vehicle, having hidden wires and secured components were an aspect the group found important to rate.

As seen in the matrix, the stacked design received the most points on average, with the square grid orientation as second. The translational motion of the two designs allowed for a high scores in feasibility, efficiency and uniqueness. The stacked grid design allows for hidden wiring of the system, which overall boosts the score of the hardware management. Both the stacked and the square design had a lot of room for scalability, both having the ablity to maximize the grid plate space. Overall the stacked design scored the highest on average and is the design that our group began prototyping.

6. System Risk Management

The group brainstormed several issues that may occur during the building of the system. Each of the problems are described below, and placed in the risk management assessment below. Each of the problems were rated the based off the probability of the issue occurring and the consequence of the problem if not solved, as shown below.

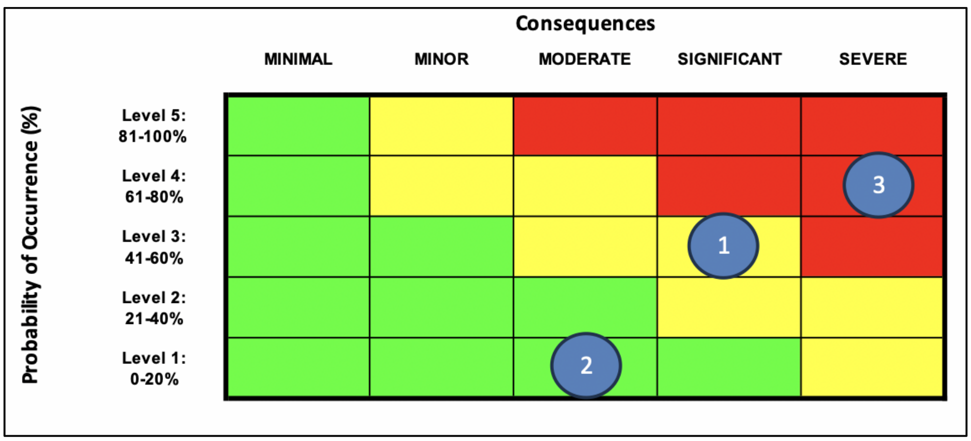


Figure 8 - Risk management Assessment Graph.

Problem one was the completion of the gripper. When previously working with the gripper, the group experienced many issues. A few being the gripper was stripped and therefore unable to be used, the goal of this issue was to get the gripper working and not strip the piece. In order to complete this task without any problems, the gripper was to be assembled as soon as possible. When assembling the gripper, each bolt was first hand-tightened, and then uniformly tightened with a screwdriver to ensure that the gripper does not strip due to too much force. This is rated a level 3 probability of occurrence with significant consequences. The group feels minorly confident in the ability to get the gripper running, but unsure about stripping the piece. Without the gripper the vehicle is unable to complete parts of task one, which is why this would be placed under moderate risk.

Problem two was keeping the group updated as the car is being built. This ensures that the group is all on the same page, and ensures each individual knows what aspects to work on and to meet the deadlines for the project. In order to tackle this issue, group meetings will be held weekly in order to speak about the future plans of the vehicle, and communication via text and email in order to keep all members updated of the current state of the vehicle. With the ability to communicate via text and email, it would be very unlikely that communication between the group will be compromised. There may be certain weeks in which a member or two are unable to make the meeting. This is considered moderate consequences since the vehicle could possibly be completed with minimum communication, but is not ideal.

Problem three is time. The group must efficiently pace the production of the vehicle in order to prevent meeting the time deadline. As experienced by all in this group, many of these components need to be constant troubleshooted, and constantly needed to be recalibrated. In order to prevent this issue from occurring, the team plans to complete all hardware components completed by week 8 in order to allow a full week of troubleshooting. The project will have individual tasks for each individual to complete which can be done at individual times. This will allow for the team to be ready for any issue come test day. This issue is very likely to happen. It's very likely that the group runs into a problem in which causes a slow down in the production of the vehicle. It is also likely that no progress is made on the vehicle, each member must also balance the work of classes. Not having enough time to troubleshoot issues towards the deadline can cause a significant loss of points. Time is the most important aspect of this vehicle, ensuring correct pacing along the 10 weeks ensures that the vehicle has the ability to perform all the necessary task.

7. Detailed Design

As the team moved further into the prototyping process that certain aspects of the design should be changed in order to improve the vehicle's ability to perform the tasks. The vehicle may have started from the initial design described in the conceptual design section, the vehicle had many changes, from new additions or a rearrangement components as a whole.

Every component used in the vehicle had its individual pins and color coordinated in order to easily problem-solve. Each component used is connected to the correct power supplies in order to prevent damage to parts. This section will cover in detail: A structural decomposition of the parts used, circuit schematics and all additional parts that were not mentioned in the conceptual design section.

7.1 Decomposition of the System

The vehicle is shown below in the figure.... The chassis of the vehicle begins with the two stacked plates being held together by two U-channels at the end of the plates. Post mount clamps are then added to each corner of the bottom grid plate. Post mount clamps are located in the opposite corner of its parallel pair. Then each motor is placed inside the post-mount clamp and tightened. The screw hubs are then connected to the motors and then tightened. The Omni-wheels are then connected to the screw hubs and tightened. The motors are then wired to the motor controllers, two motors are connected to each motor controller, creating a total of 2 motor controllers. The motor controllers are located on the bottom grid plate, held down by nylon screws to prevent grounding issues with the component.

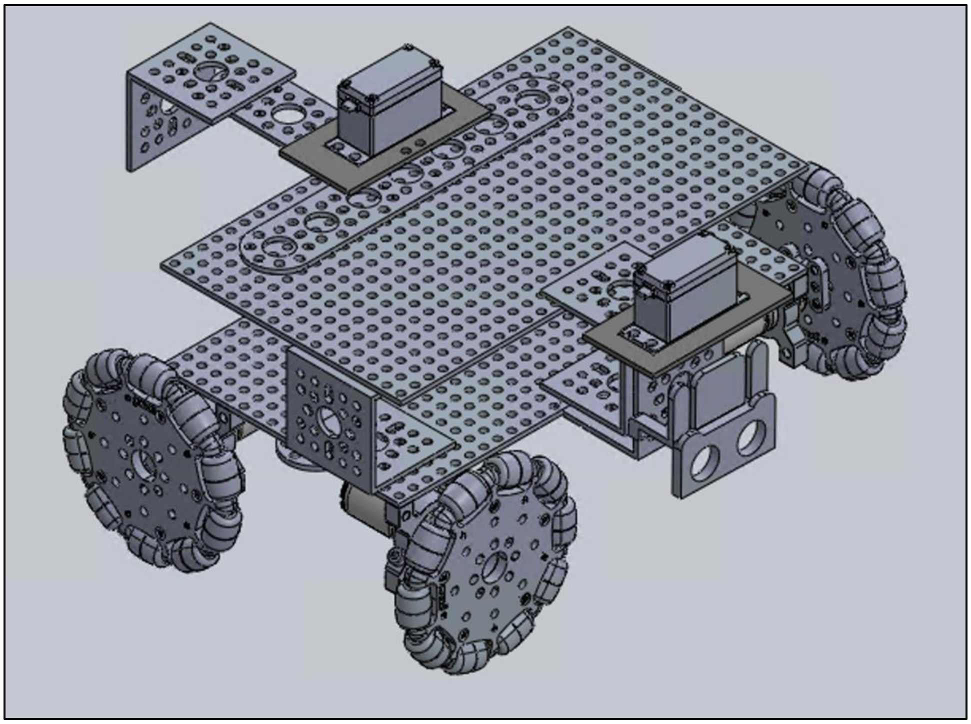


Figure 9 - Isometric view of Solidworks Drawing of vehicle.

A U-channel is connected to the bottom grid plate, creating a small overhang under the vehicle. Then a 7-hole end pattern plate is connected to the U-channel, housing the two 3D printed mounts, which holds a color sensor each. Attached to the top plate are the gripper and the IR sensor mount, placed on opposing sides of the vehicle. The IR sensor held by a 7-hole end pattern plate connected to a servo mount and a servomotor. The servo motor is connected to a 5-hole end pattern plate, with an L-channel holding the IR sensor. The gripper is connected to a U-Channel mounted to the top grid plate. Attached to the U-channel is a L-channel held together by a bolt and spacers. Attached to the L-channel is a custom 3D printed mount which holds a ultrasonic sensor and a color sensor.

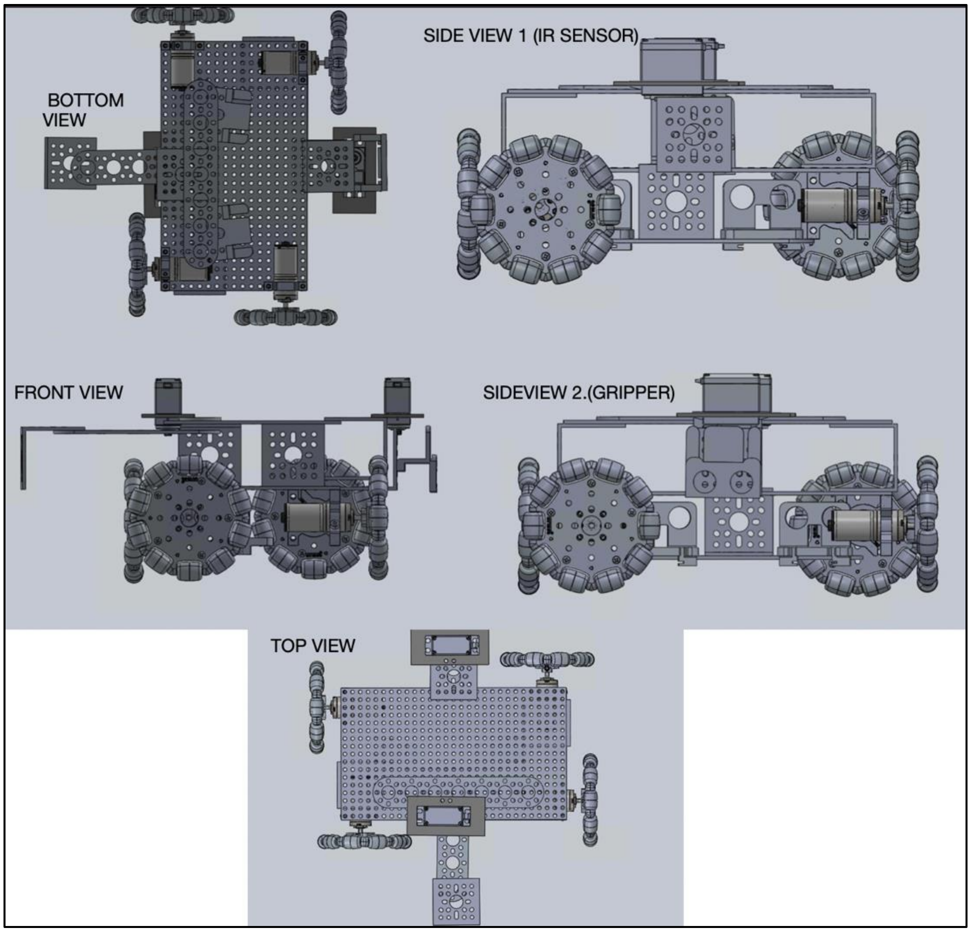


Figure 10 - Different Views of SolidWorks Drawings.

7.2 System Wiring

Here we have the final layout of the schematic for Wall-E. We almost all of the forty one available pins on the Teensy4.1 Microcontroller for a specific function. The main block diagram has roots from a similar one created in an Embedded Systems class taught by Dr. Martins. Who helped the class understand what to look for in a system wiring diagram and what to make sure to have for future professor who show interest in the block diagram. The main point of a block diagram is to clearly illustrate the wiring of the device and show how all the components come together to form the final composition that is Wall-E. Most pins go directly into the microprocessor but out of all these pins six pins are input while the rest are all output pins giving direction off of the microcontroller infrastructure. We used the two Infared sensors for measuring the size of the acquired box and the obstacle avoidance. These components each used 5V and used 20mA of power.

The next component is the ultrasonic sensor that was used to determine the position of the pedestal, where the box was located. It was originally going to be used for obstacle avoidance as well but after trial and error it was found to not work at angles since the sound would not travel back to the ultrasonic sensor in that instance. An Infared does so the project was pivoted and used an Infared sensor. The ultrasonic sensor uses a trigger pin that dishes out a signal and the echo pin receive it and determines the distance of objects depending on the duration of the time it took to return the component. This combination is combined into the teensy and used to determine to determine the distance of objects using 5 V and 15 mA.

There are additionally three RGB sensors on the Teensy each with five wires that are needed to operate correctly. There is one PWM pin and four GPIO pins for each color. These colors being: red, green, blue. white, and black. Two of the RGB sensors are at the bottom of the vehicle and used to line track a path of a certain color. There are different colored paths that the vehicle must stay on depending on the color and shape of the box. The shape comes from the Infared sensor while the color comes from the remaining RGB sensor. These three work in tandem to be able to dictate and analyze where Wall-E is concurrently. They occupy 5V each and 1.4 A.

The one servo motor on the vehicle is responsible for maneuvering the Infared sensor so it is able to locate walls around it without needing to rotate. It uses 7.4 Volts.

The last component connected to the Teensy are the motor drivers who are the brains behind the movement in the car. They tell the motors when to move according to the instructions provide in the code by the Teensy. These were causing the most problems for the group in the beginning of the quarter as team five had to rewire and re do the design of the entire vehicle so it would be able to do simple movement. Even using new wires everything was started was scratch to flush out the troubleshooting error that kept avoiding the team for weeks.

The main power supply comes from a 12V rechargeable 12000 mAh battery that was attached directly to the driver modules and to the voltage regulators to convert the 12V to a usable 7.4V and 5V for the rest of the components. Each part meticulously placed in order to be able to give functionality to Wall-E.

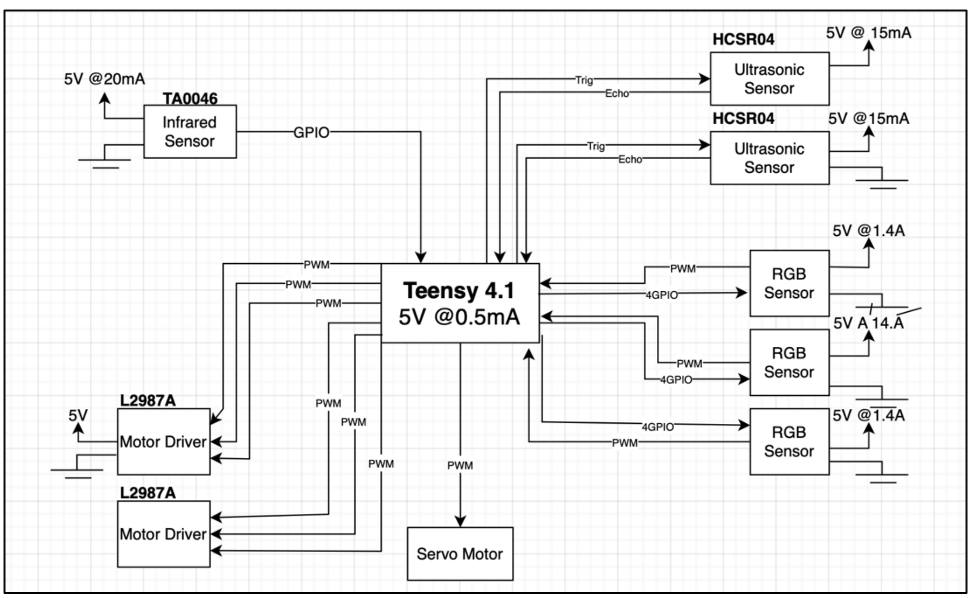


Figure 11- Wall-E Schematic Block Diagram

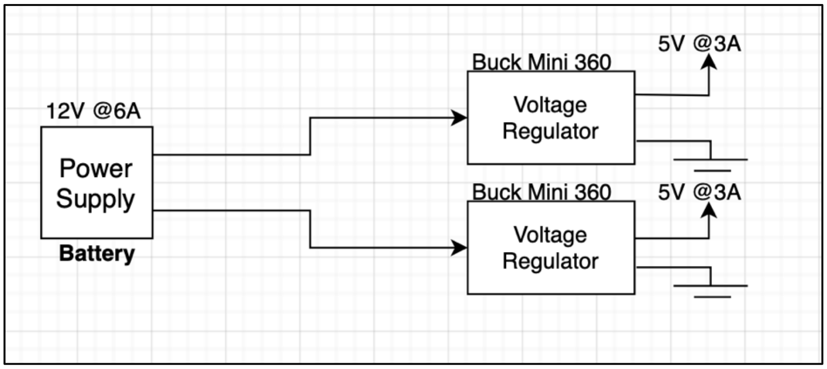


Figure 12– Power Supply Schematic Block Diagram

		Conncection	Teensy pin	Teensy pin	Connection		
	PWM		GND	5V			
	PWM		0	GND			
	PWM		1	3.3V			
Driver Module1	PWM	enC	2	23	GS3	PWM	RGB
	PWM	in5	3	22	GS2	PWM	Grippper
	PWM	in6	4	21	GS1		
	PWM	enD	5	20	GS0		
	PWM	in7	6	19	G_senserOUT	PWM	
	PWM	in8	7	18		PWM	
Driver Module 2	PWM	enA	8	17	irSensor(G)		IR Gripper
	PWM	in1	9	16	irSensor(O)		IR Obstacle
	PWM	in2	10	15	gripperPin	PWM	Servo Gripper
	PWM	enB	11	14	obstaclePin	PWM	Servo Obstacle
	PWM	in3	12	13	PushButton	PWM	Eplzon Board
			3.3 V	GND			
	PWM	in4	24	41	LED "Obstacle"		
	PWM		25	40	LED "Ramp"		
Ultrasonic		echo	26	39	LED "Gripper"		
		trigger	27	38	LED "Stall"		
RGB	PWM	L_sensorOUT	28	37	R_sensorOUT	PWM	RGB
Tracking 1	PWM	LS3	29	36	RS3	PWM	Tracking 2
Left Side		LS2	30	35	RS2		Right Side
		LS1	31	34	RS1		
		LS0	32	33	RS0	PWM	

Figure 13- Pin Assignment Diagram for Teensy Board

7.3 Software Architecture

Developing the code for the system was approached in a piece by piece and algorithmic sense. Majority of the fundamental functions of the system, such as movement or reading sensors, were devoted their own methods so that they can be used to develop algorithms for tasks 1 and 3. For example, the general logic for obstacle avoidance was to call the call the moveForward() while calling the readIRSensor() function. Once the sensor detected something, then the algorithm for the task would progress. Most of the logic for the system was to call fundamental functions of the system until a flag or value was raised to a threshold to progress the algorithm until the task was completed.

Then each of these tasks were devoted their own functions so that they could easily be tested on an individual basis within the main loop. Some functionality proved to be too complex to keep within one function, so a few functions were created exclusively for other functions in order to simplify them. Doing so allowed for the code to be debugged more easily.

7.4 Additional Features

The group brainstormed various ideas to add to the system in order to improve the functionality of the system or ideas that may add to the wow factor of the vehicle. These ideas did not make it to the final design due to time constraints and other circumstances, but still believed that these additions would have made the vehicle much better.

One of the initial ideas of this vehicle was to create a gripper arm which can move along the horizontal plane in order to change the systems center of gravity, ultimately allowing for an easier ascent up the ramp. We found that this had minimal impact on the vehicles ability to go up the ramp, and found that it was unnecessary to use, and settled on the gripper attached to the edge of the grid plate.

Another idea created was a rotating motor mount. A disadvantage of our design is the lack of power to go up the ramp. For the design, Raul created 3D printed mounts that would connect to a servo motor and allow for two motors to rotate to have wheels on only two sides. This would allow for the vehicle to move upward with the power of all four motors vs the two allowing for the vehicle to move more weight. Ultimately the group ran out of time towards the end of production and was unable to implement this design in to the vehicle.

The last idea that the group had was the implementation of a speaker. The group believed that the usage of a speaker would increase our scores in the extra feature category. Although this was a great idea, due to the time constraint the idea of the speaker was not carried out.

8. System Testing and Verification

This section describes all of the testing and measurements conducted for the system.

8.1 Test and Evaluation Master Plan

The Test and Evaluation Master Plan serves to outline the objectives and approaches taken to test and evaluate the system while undergoing development, to ensure better quality and reliability. Raul oversaw testing and verification of the electrical components. Evan oversaw testing and verification of the code. Phillip and Ana oversaw testing and verification of the mechanical components.

Depending on the component, specific measures were taken to evaluate and verify the functionality of it. The testing requirements are detailed in the following sections.

8.1.1 Testing Wheels, Motors and Motor Modules

8.1.1.1 Test Plan

To ensure that the wheels are spinning properly. Verify that the motors are receiving proper power supply from the motor modules. Verify that the motor modules are receiving proper power supply, and that the wiring is correct according to the diagram. The battery terminals must be within +/- 5% of 12 V and 0V for the positive and negative terminals respectively.

8.1.1.2 Test Preparation:

Ensure that the battery is turned on. Have a USB cable nearby to upload run the motor test code. When uploading code to the Teensy Board, turn off the battery. Locate a large, smooth and flat surface to test the wheels and motors on. Acquire a multimeter to test voltage points.

8.1.1.3 Test Procedure:

1. Upload the motor test code to the Teensy. After uploading is finished, unplug the Teensy.
2. Turn on the battery. The vehicle will then begin moving. Verify that the vehicle moves in the following order: Forward, Backward, Left, Right, Clockwise rotation, counterclockwise rotation.
3. Test for voltage on the motor module at the points where the battery connects.

8.1.1.4 Test Results:

Table 1 - Motor and Wheel Testing Results

Point Measured	Value
Battery Power Supply Positive Terminal	11.9 V
Battery Power Supply Negative Terminal	0.0 V

After running the test code and testing for voltage at the battery terminals, the operation of the basic movement functions was verified to be functioning properly, and the motor modules were receiving proper power supply within the specified limits.

8.1.2 Testing the Gripper

8.1.2.1 Test Plan

To ensure that the gripper responds to the code properly. To confirm the values for the open, big box, and small box positions. Verify that the gripper stops closing when it detects a box. Confirm that the gripper is capable of safely holding boxes of two different sizes.

8.1.2.2 Test Preparation:

Ensure that the battery is turned on. Have a USB cable nearby to upload and run the gripper test code. When uploading code to the Teensy Board, turn off the battery.

8.1.2.3 Test Procedure:

1. Upload the gripper test code to the Teensy. After uploading is finished, unplug the Teensy.
2. Turn on the battery. The gripper will then begin cycling between the 3 different positions. Hold the big box between the gripper teeth until it closes on it. The gripper should stop cycling and hold the box without crushing it.
3. If the gripper doesn't stop cycling, turn off the vehicle and recalibrate the gripper IR sensor until it stops the gripper cycling when a box is close to it.

4. If the gripper doesn’t close enough or closes too much on the box, turn off the vehicle and adjust the gripper position value for the big box in the code until it grips the box firmly without crushing the box.
5. Repeat the above steps for the small box instead.

8.1.2.4 Test Results:

Table 2 - Gripper Testing Results

Open Position Value	91
Big Box Position Value	61
Small Box Position Value	41

8.1.3 Testing the Ultrasonic Sensor

8.1.3.1 Test Plan

To evaluate the ultrasonic sensor and verify that it can accurately detect the distance of objects in front of it so that the system may approach objects without getting too close for tasks 1 and 3.

8.1.3.2 Test Preparation

Acquire an appropriately sized object, such as a pedestal, that the ultrasonic sensor could detect. Ensure that the vehicle has a clear and flat surface to test on. Ensure that the battery is turned on. Have a USB cable nearby to upload and run the gripper test code. When uploading code to the Teensy Board, turn off the battery. Acquire a meter stick to verify distance measurements.

8.1.3.3 Test Procedure:

1. Upload the ultrasonic test code to the Teensy. After uploading is finished, keep the Teensy plugged in so that it can output values to the serial monitor.
2. The serial will begin receiving values from the ultrasonic sensor. Place the object within half a meter away from the ultrasonic sensor with the meter stick parallel to the side.
3. Confirm that the ultrasonic measurements are accurate to the objects actual distance according to the meter stick. If there is error, adjust the scalar value in the test function until the ultrasonic sensor measurements are accurate.
4. Validate that the ultrasonic sensor can detect the object getting closer or further away by moving the object. The serial readings should change accordingly. If not, reevaluate the test function.

8.1.3.4 Test Results:

After adjusting the test function, the ultrasonic sensor was capable of detecting distance in front of it with acceptable accuracy.

8.1.3 Testing the Color Sensors

8.1.3.1 Test Plan

To test and calibrate the color sensors so that the color sensors can correctly detect colors in front of it so that the system can follow colored paths and detect the color of the box for Task 1.

8.1.3.2 Test Preparation

Secure a well-lit testing environment so that the color sensors can be calibrated correctly. If possible, secure a flat sheet of paper with strips of different colors across it to be used for calibrating the color sensors for different colors. Acquire a red and a blue box for the gripper color sensor.

8.1.3.3 Test Procedure:

1. Upload the color sensor test code to the Teensy. After uploading is finished, keep the Teensy plugged in so that it can output values to the serial monitor.
2. Verify that the pinouts match those in the code and that the sensors are wired correctly.
3. The serial will begin reading values from all 3 of the color sensors. Going color by color, place the sheet of colored strips under the system so that both underside color sensors are directly above the color. Record the values from the serial monitor to the respective sensor's matching color array (i.e. with red underneath, record the values to RightSensorRed[] and LeftSensorRed[]). Values are in order of red, green, then blue, corresponding to the order from the serial monitor.
4. Repeat step 2 for colors Red, Green, Blue, Black, White, and Yellow
5. Repeat step 2 for the gripper color sensor instead but using the red and blue boxes instead.
6. After completing all the above steps, reupload the test code, and begin testing each of the color sensors by placing different colors in front of them and verify that they are outputting the correct colors. If there are any errors, repeat steps 1 – 4.

8.1.3.4 Test Results:

Table 3 – Color Sensor Result Values

	Right Sensor	Left Sensor	Gripper Sensor
Red	174, 190, 170	20, 130, 120	20, 60, 60
Blue	15, 65, 10	230, 80, 30	50, 35, 40
Green	230, 160, 230	220, 140, 200	-
Black	230, 230, 230	290, 290, 290	-
White	0,0,0	0,0,0	-
Yellow	130, 40, 130	20, 50, 150	-

1. After calibrating the color sensors, the color sensors were able to properly detect colors with satisfactory accuracy. However, many times throughout development, recalibration of the color sensors was required, else the system would cease to function properly. Even glancing over the data table above, there are inconsistencies in relativity between individual values of different sensors for the same color. After finishing development, the only conclusion that could be drawn was that one of the sensors had an issue.

8.1.3 Testing the IR Sensors

8.1.3.1 Test Plan

IR sensors are needed by the system to be able to detect how close the gripper-claws are to a box, as well as to be able to avoid obstacles. The plan for testing is to adjust the potentiometers on both of the IR sensors so that they respond to an appropriate distance for their respective tasks.

8.1.3.2 Test Preparation

All that is needed is a USB cable to provide power to the Teensy, and an object to place in front of each of the IR sensor. As well as a screwdriver to adjust the on-board potentiometer.

8.1.3.3 Test Procedure:

1. Plug in the Teensy to provide power to the IR sensors.
2. Whenever either of the IR sensors detects an object within its set range, an on-board LED will flash. We can use this to adjust the IR sensor range without having to upload code.
3. For the gripper IR sensor, use a box and place it directly in front of the sensor. Adjust the IR sensor potentiometer until the LED turns off. After doing so, adjust the potentiometer slightly until the LED turns back on.
4. Repeat step 3 for the obstacle avoidance IR sensor, except place an object about half a foot away.

8.1.3.4 Test Results:

After calibrating the IR sensors, each of the sensors was capable of detecting objects within their desired ranges and properly aided the system in performing the tasks correctly.

Table 4 – Testing Check Table

Component	Requirement	Verification / Validation			Analysis
		Inspection	Demonstration	Test	
Wheels and Motors	Movement Functions	x	x	X	Properly functioning. Wheels need to be refastened to motors semi-frequently to avoid slippage.
Gripper	Pickup box safely	x	X	x	Properly functioning.
Ultrasonic Sensor	Accurately detect distance of objects	x	x	x	Properly functioning, but quick-moving objects cause errors.
Color Sensors	Accurately detect colors	x	x	x	Properly functioning but requires frequent retesting.
IR Sensors	Detect appropriate distance for respective tasks	x	x	x	Properly functioning.

9. System Analysis and System Performance Metrics

9.1 Payload Capacity

To find the coefficient of friction of the ramp, we assume the weight of the vehicle to be about 6 kg, and carrying a load of 1 kg up the ramp. The force of gravity is assumed to be 9.81 m/s, and the ramp is at a position of 18.5 degrees. We begin find the y force in the normal coordinate system. Then a new coordinate system is created oriented 18.5 degrees from the normal, from this point are able to solve the various components and find a friction coefficient of 0.364.

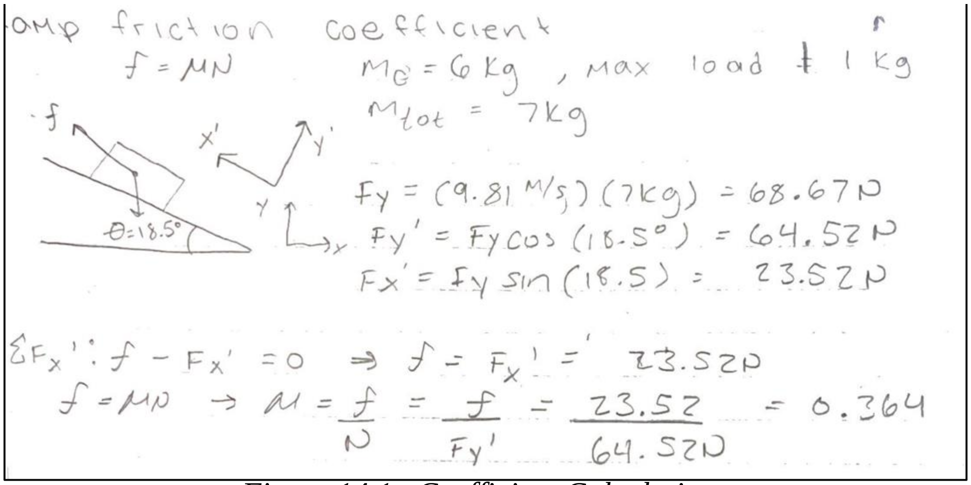


Figure 14.1– Coefficient Calculations

9.2 Gripper Stripping Calculation

Below are calculations for the stripping of the gripper gear. For the gripper, there are plastic gears that attach to the servo gear. If the gripper is tightened too much, it puts the gripper gear at risk to strip. Below contains two calculations. The first is the calculation for the gear stripping at the highest point of single tooth contact, meaning the failure if the force is concentrated on a single tooth of the gear and was found to be 11.2N. In the case of the gripper, the gripper has full contact with the servo gear at all times, creating an even force along all teeth. To fully strip the gripper gear, the servo must input a force of 33.04 N*mm of force.

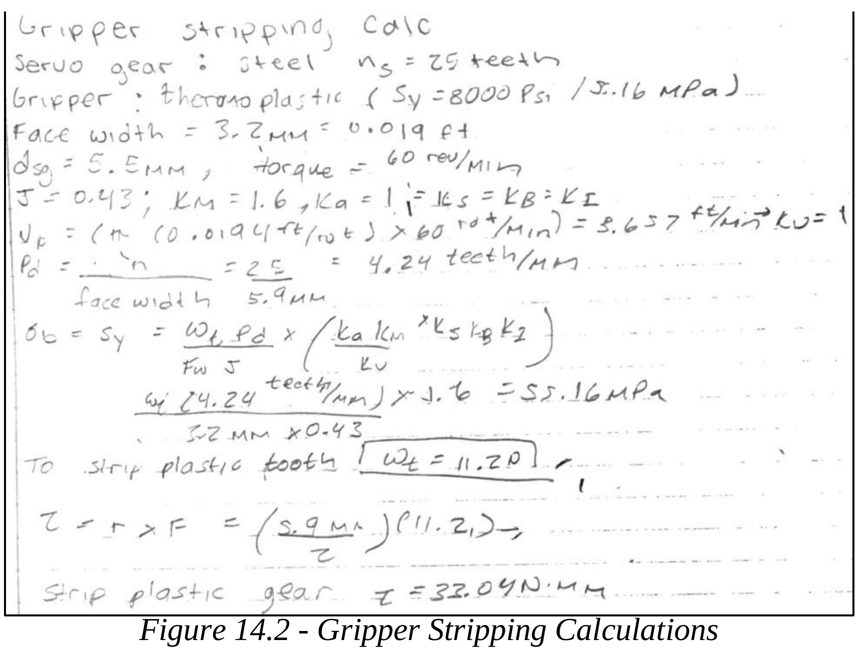
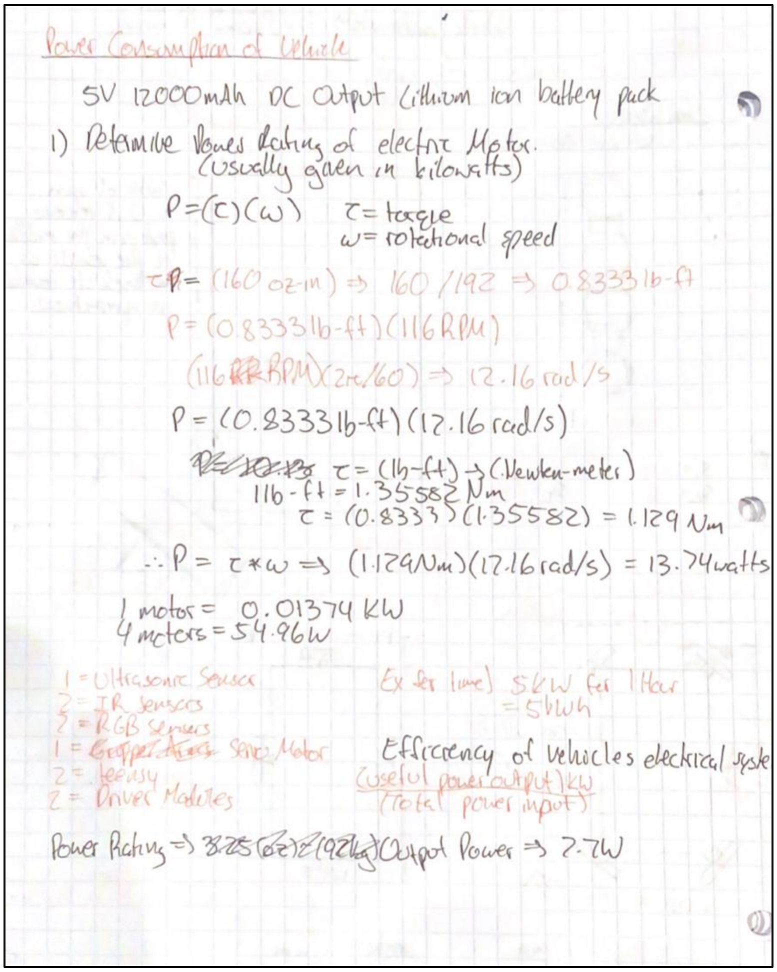


Figure 14.2 - Gripper Stripping Calculations

9.3 Power Distributions Equations:



Power Consumption of Vehicle

5V 12000mAh DC Output Lithium ion battery pack

1) Determine Power Rating of electric Motor.
(usually given in kilowatts)

$P = (\tau)(\omega)$ τ = torque
ω = rotational speed

τ = (160 oz-in) ⇒ 160 / 192 ⇒ 0.8333 lb-ft

P = (0.8333 lb-ft)(116 RPM)

(116 RPM)(2π/60) ⇒ 12.16 rad/s

P = (0.8333 lb-ft)(12.16 rad/s)

τ = (lb-ft) → (Newton-meter)
1 lb-ft = 1.35582 Nm
τ = (0.8333)(1.35582) = 1.129 Nm

∴ P = $\tau * \omega$ ⇒ (1.129 Nm)(12.16 rad/s) = 13.74 watts

1 motor = 0.01374 KW
4 motors = 54.96 W

1 = Ultrasonic Sensor
2 = IR Sensors
2 = RGB Sensors
1 = Servo Motor
2 = Teensy
2 = Driver Modules

Ex for time) 5KW for 1 Hour
= 5kWh

Efficiency of vehicles electrical syste

$\frac{\text{(useful power output) kW}}{\text{(Total power input)}}$

Power Rating ⇒ 3825 (oz) ≈ (92kg) Output Power ⇒ 2.7W

Figure 15– Power Distribution Calculations page 1

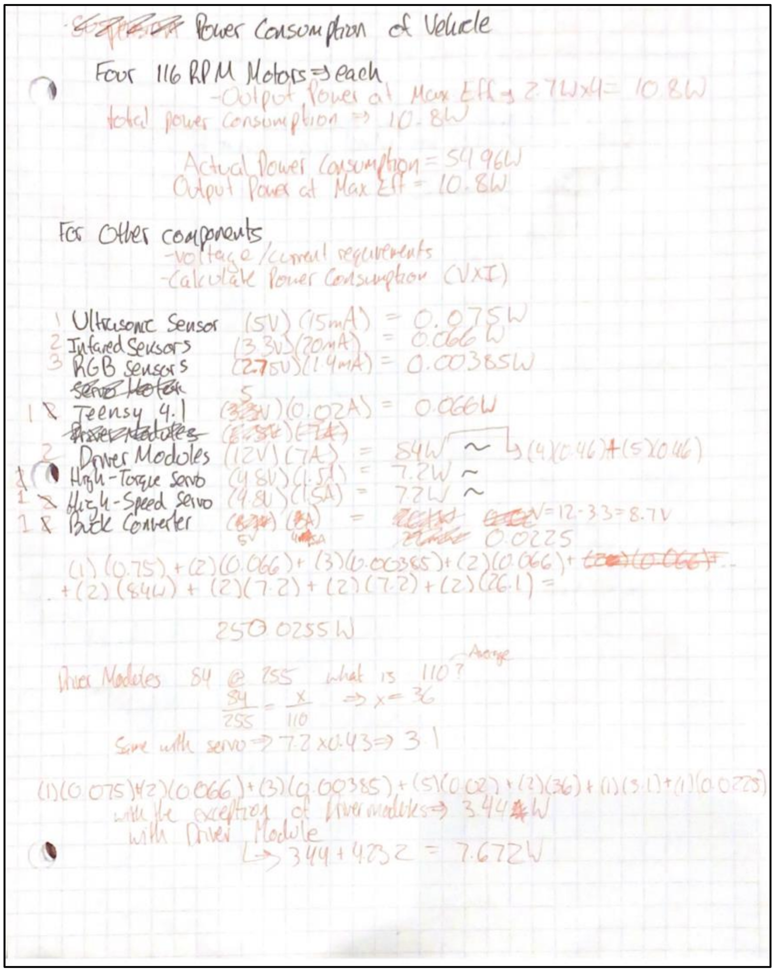


Figure 16– Power distribution calculations page 2

9.4 - Stability Equations:

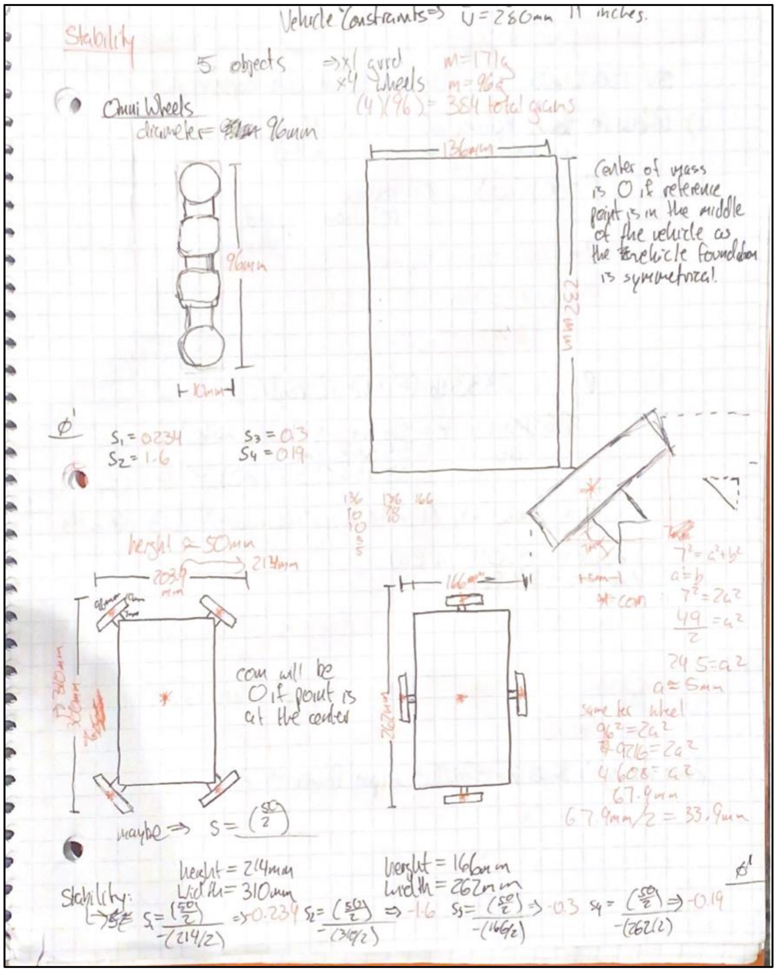


Figure 17– Stability Calculations

9.5 - Obstacle Course Analysis:

The group found it efficient to be able to take advantage of the few obstacle combinations and use probability and statistics to be able to write a code that would determine the code after its second turn.

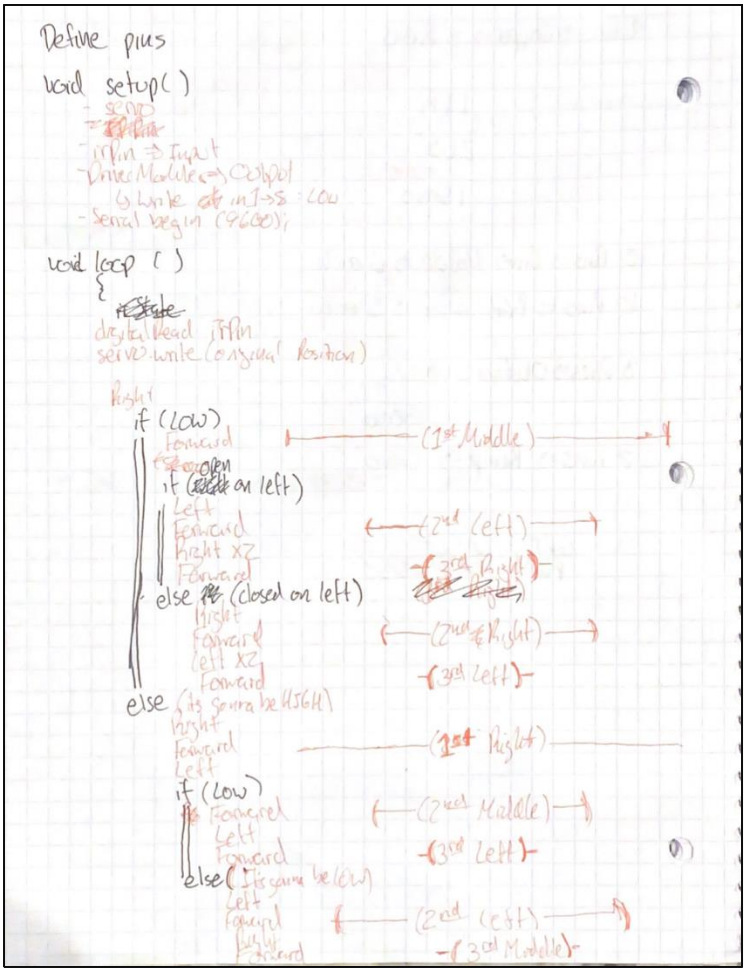
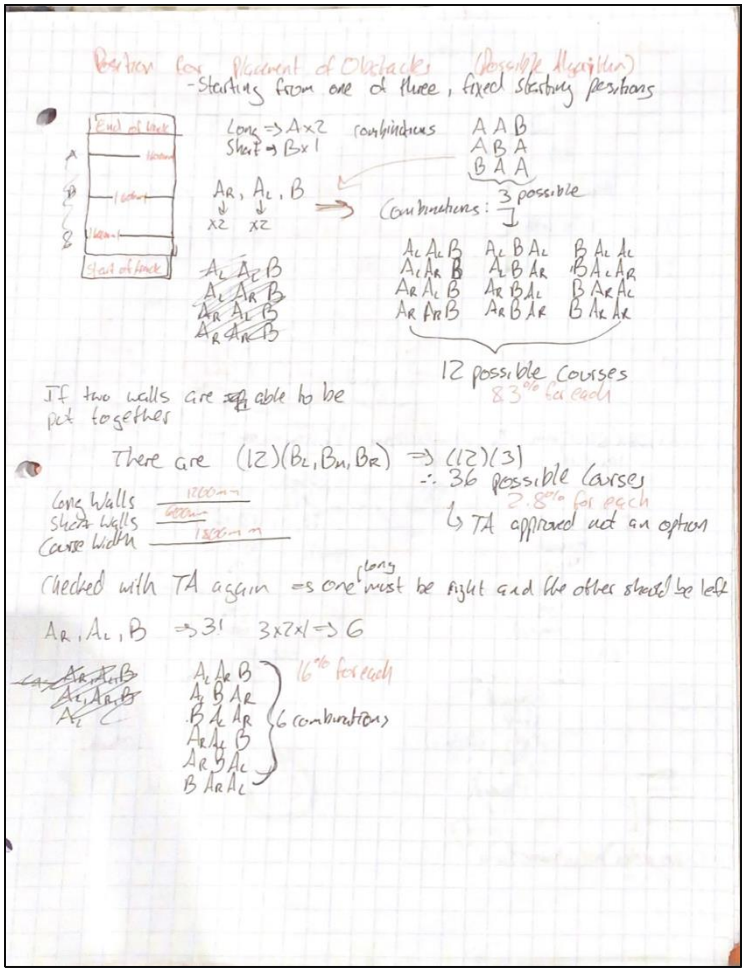


Figure 18– Task 3 analysis page 1



Position for Placement of Obstacles (Possible Algorithm)
- Starting from one of three, fixed starting positions

End of track
Start of track

Long ⇒ A×2
Short ⇒ B×1

combinations
AAB
ABA
BAA
3 possible

A_R, A_L, B
×2 ×2

Combinations:

$A_L A_L B$	$A_L B A_L$	$B A_L A_L$
$A_L A_R B$	$A_L B A_R$	$B A_L A_R$
$A_R A_L B$	$A_R B A_L$	$B A_R A_L$
$A_R A_R B$	$A_R B A_R$	$B A_R A_R$

12 possible courses
8.3% for each

If two walls are able to be put together

There are $(12)(B_L, B_M, B_R) \Rightarrow (12)(3)$
∴ 36 possible courses
2.8% for each
↳ TA approved not an option

Long Walls 1200mm
Short Walls 600mm
Course Width 1800mm

Checked with TA again ⇒ one long must be right and the other should be left

$A_R, A_L, B \Rightarrow 3!$ $3\times2\times1 \Rightarrow 6$

$A_L A_R B$
$A_L B A_R$
$B A_L A_R$
$A_R A_L B$
$A_R B A_L$
$B A_R A_L$

6 combinations
16% for each

Figure 19– Task 3 analysis page 2

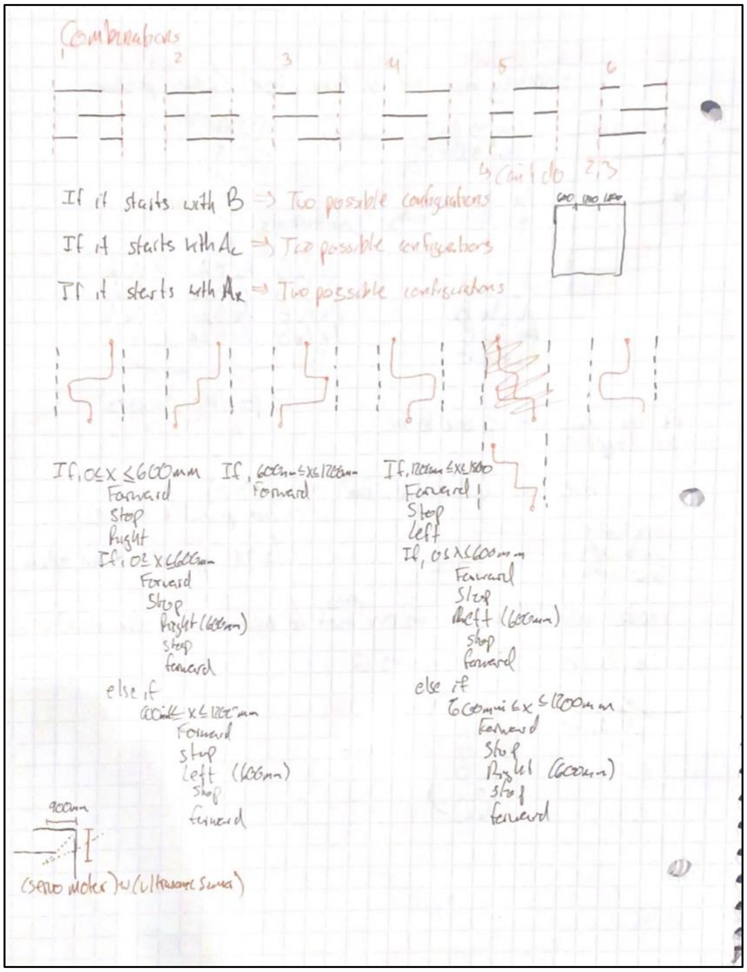


Figure 20 – Task 3 analysis page 3

Ideas that weren't materialized:

Suspension and Bevel gears:

These were ideas to get an advantage on the ramp and create a force of four wheels that were able to go along bumps as opposed to two wheels from the regular design. The idea was solid but unfortunately the prototypes had a couple errors which the group didn't have time to revise in time to apply to the final vehicle.

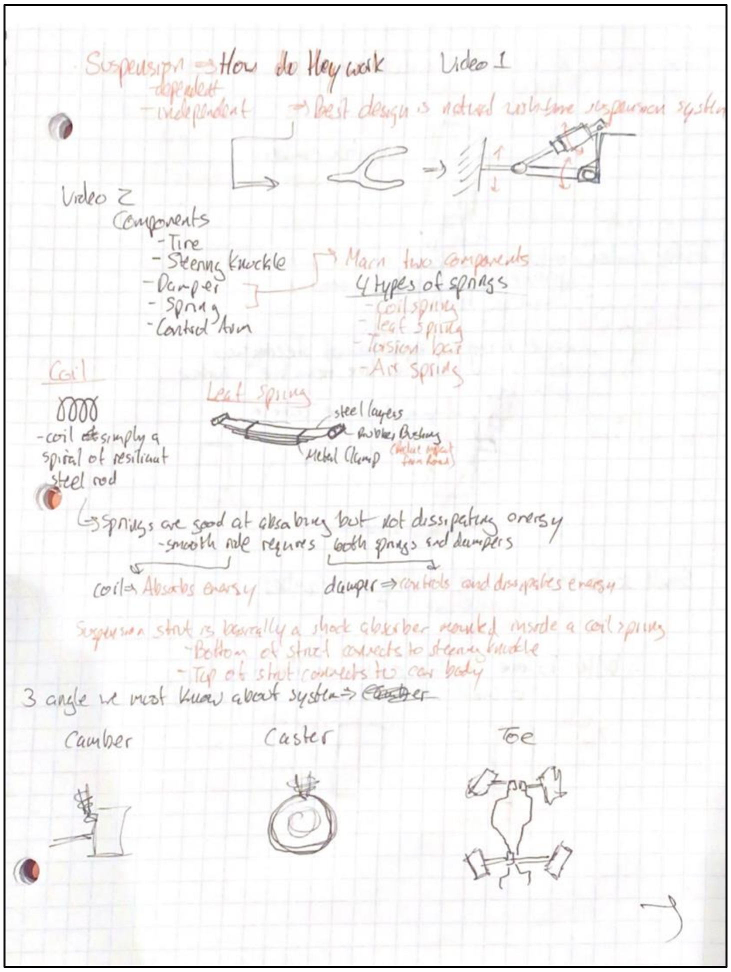


Figure 21– Suspension and Bevel Gears Concept Design page 1

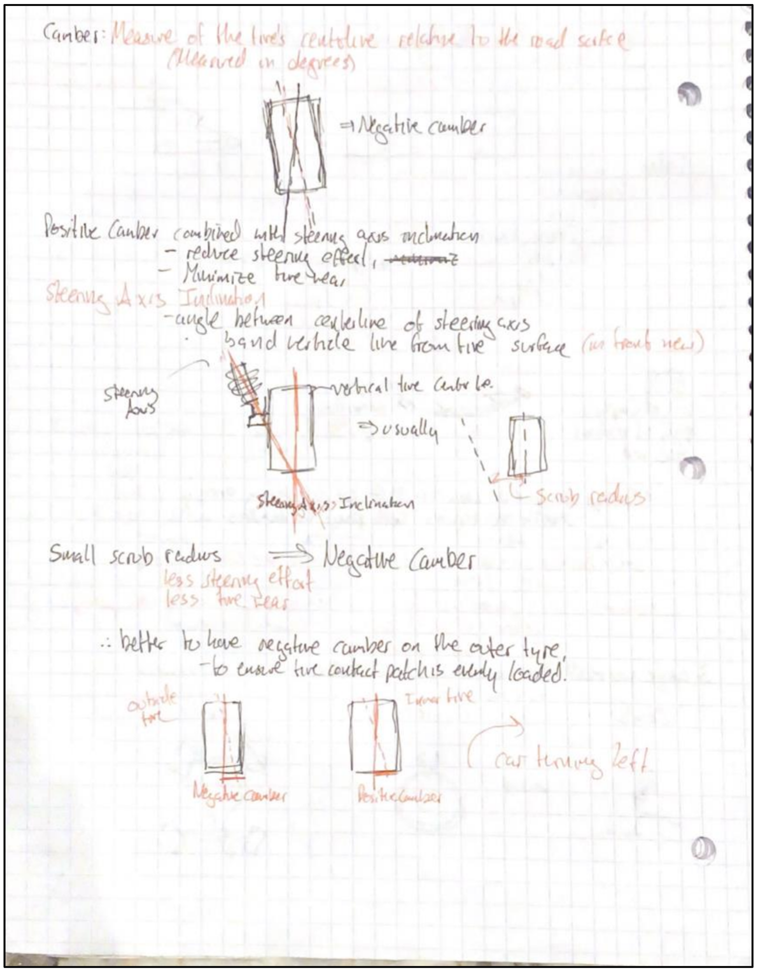


Figure 22– Suspension and Bevel Gears Concept Design page 2

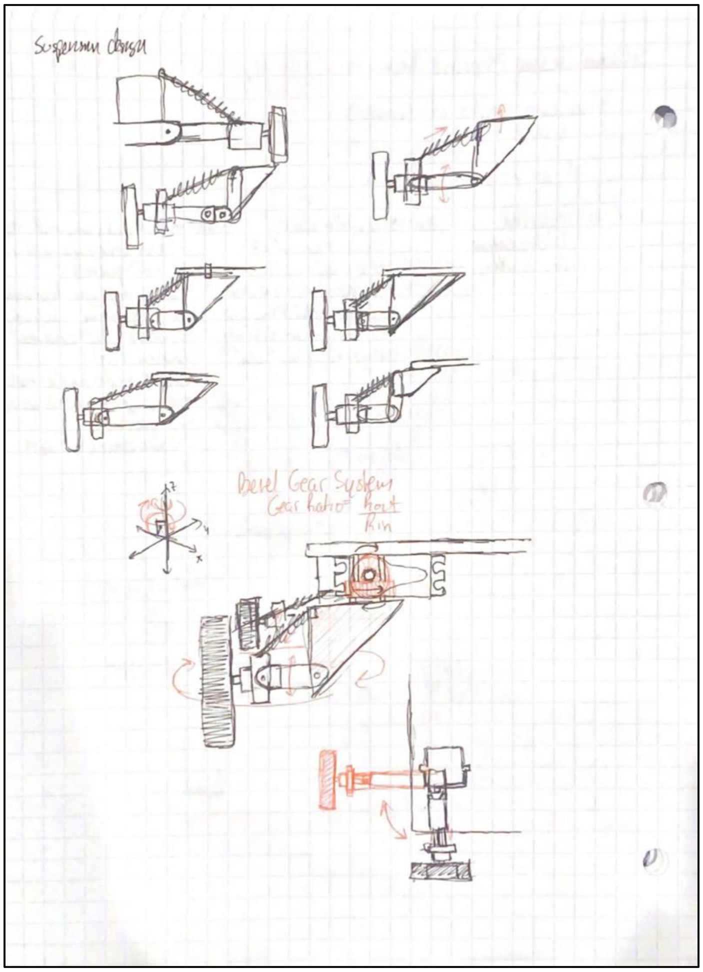


Figure 23– Suspension and Bevel Gears Concept Design page 3

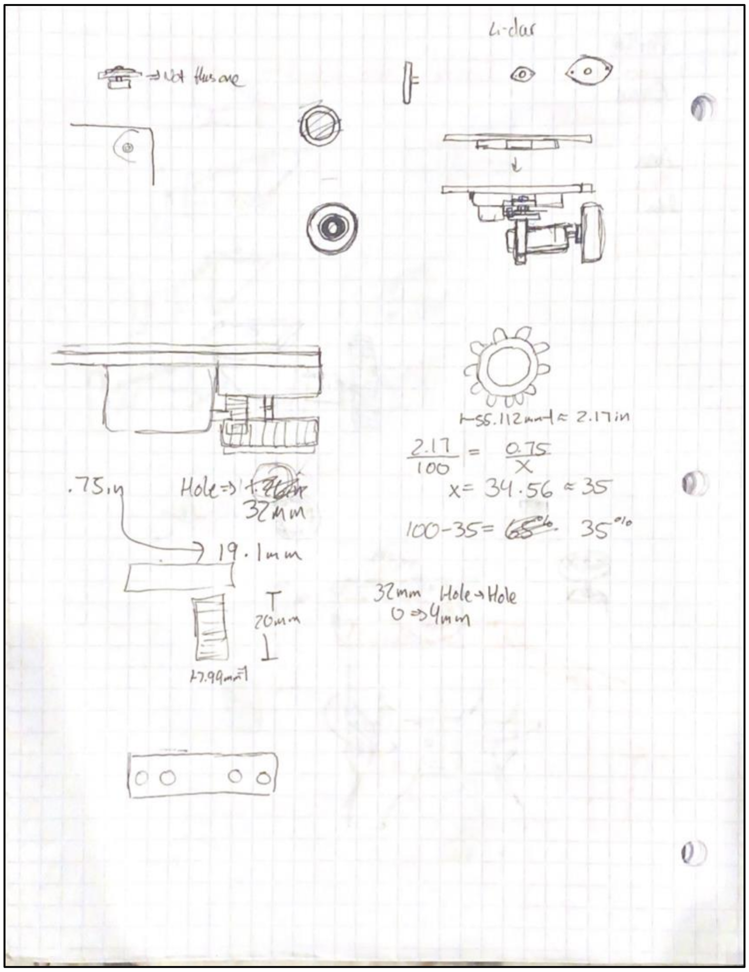


Figure 24– Suspension and Bevel Gears Concept Design page 4

10. Summary

All in all these ten weeks have been a culmination of the different sectors of engineering. From the coding experience we get from the computer engineering parts. To the creation of the vehicle from the essence from mechanics engineering. All the way to the meticulous wiring from the knowledge learned from the electrical engineers.

Every single one of these played a part while apply the knowledge learned in not only Engineering Integration I, but in the first three yers of fundamental of engineering systems here at DU. These topics were used to create a vehicle that is able to adapt to three different t terrains and obstacles. The first of which is picking up an object, being able to identify the color and follow a path accordingly to drop off the box at a pedestal. The second was being able to go up a ramp while carrying and pushing it pulling a weight. This was done on an inclined surface that test the friction coefficient of the vehicle. The final task was being able to maneuver through an obstacle course with three sets of wall. This would test the awareness of the vehicle and how it would be able to be agile in a specific environment with changing terrain.

These three tasks were all in our toolbox to achieve. The university of Denver has given us the classes necessary to materialize this project. From that I want to my group really wanted to put an edge on our vehicle an be able to think outside the box. This experience helped us round out our engineering foundation to be able to transition into more projects in the future.

11. Documentation and Acknowledgments

ENGR 2620 Spring Quarter Integration Project Spec v2.0 (University of Denver, ENGR-2620-01)

ENGR 2620 Team_Inventory (University of Denver, ENGR-2620-01)

External Help:

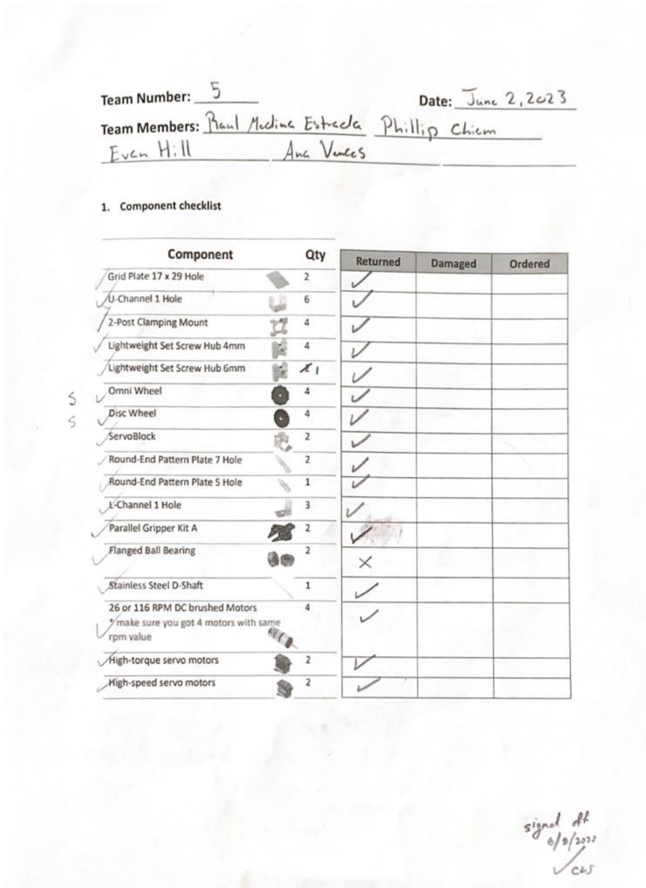
Chris Ramos (University of Denver, ENGR-2620-01)

Sam Mattei (University of Denver, ENGR-2620-01)

Chathura Semasinghe (University of Denver, ENGR-2620-01)

Appendix A

Component Checklist



Team Number: 5 Date: June 2, 2023

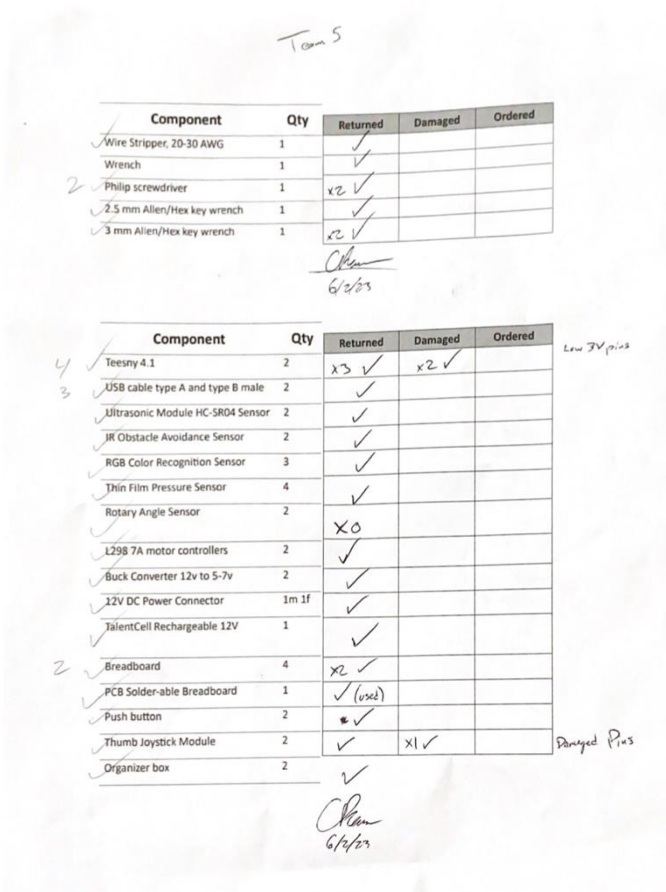
Team Members: Raul Medina Estrada, Phillip Chiem, Evan Hill, Ana Vaces

1. Component checklist

Component	Qty	Returned	Damaged	Ordered
Grid Plate 17 x 29 Hole	2	✓		
U-Channel 1 Hole	6	✓		
2-Post Clamping Mount	4	✓		
Lightweight Set Screw Hub 4mm	4	✓		
Lightweight Set Screw Hub 6mm	~~4~~ 1	✓		
5 Omni Wheel	4	✓		
5 Disc Wheel	4	✓		
ServoBlock	2	✓		
Round-End Pattern Plate 7 Hole	2	✓		
Round-End Pattern Plate 5 Hole	1	✓		
L-Channel 1 Hole	3	✓		
Parallel Gripper Kit A	2	✓		
Flanged Ball Bearing	2	×		
Stainless Steel D-Shaft	1	✓		
26 or 116 RPM DC brushed Motors *make sure you got 4 motors with same rpm value	4	✓		
High-torque servo motors	2	✓		
High-speed servo motors	2	✓		

signed off
6/2/2023
✓ CAS

Figure 25-Component Checklist



Team 5

	Component	Qty	Returned	Damaged	Ordered
	Wire Stripper, 20-30 AWG	1	✓		
	Wrench	1	✓		
2	Philip screwdriver	1	x2 ✓		
	2.5 mm Allen/Hex key wrench	1	✓		
	3 mm Allen/Hex key wrench	1	x2 ✓		

6/2/23

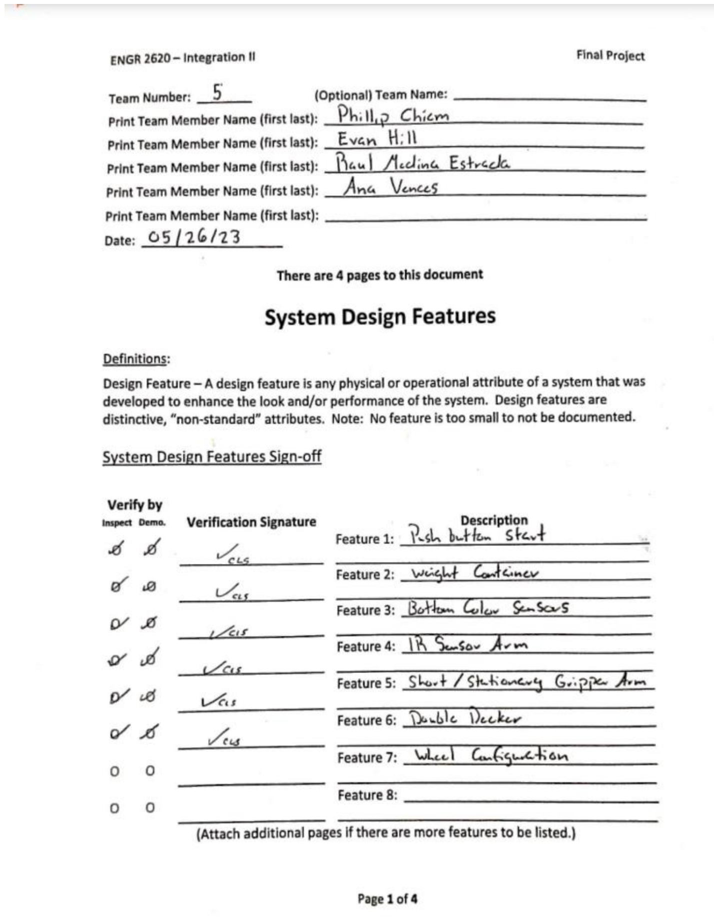
	Component	Qty	Returned	Damaged	Ordered	
4	Teesny 4.1	2	x3 ✓	x2 ✓		Low 3V pins
3	USB cable type A and type B male	2	✓			
	Ultrasonic Module HC-SR04 Sensor	2	✓			
	IR Obstacle Avoidance Sensor	2	✓			
	RGB Color Recognition Sensor	3	✓			
	Thin Film Pressure Sensor	4	✓			
	Rotary Angle Sensor	2	x0			
	L298 7A motor controllers	2	✓			
	Buck Converter 12v to 5-7v	2	✓			
	12V DC Power Connector	1m 1f	✓			
	TalentCell Rechargeable 12V	1	✓			
2	Breadboard	4	x2 ✓			
	PCB Solder-able Breadboard	1	✓ (used)			
	Push button	2	* ✓			
	Thumb Joystick Module	2	✓	x1 ✓		Damaged Pins
	Organizer box	2	✓			

6/2/23

Figure 26-Component Checklist

Appendix B

Task Performance Sign Off



ENGR 2620 – Integration II

Final Project

Team Number: 5 (Optional) Team Name: ______

Print Team Member Name (first last): Phillip Chiem

Print Team Member Name (first last): Evan Hill

Print Team Member Name (first last): Raul Medina Estrada

Print Team Member Name (first last): Ana Vences

Print Team Member Name (first last): ______

Date: 05/26/23

There are 4 pages to this document

System Design Features

Definitions:

Design Feature – A design feature is any physical or operational attribute of a system that was developed to enhance the look and/or performance of the system. Design features are distinctive, "non-standard" attributes. Note: No feature is too small to not be documented.

System Design Features Sign-off

Verify by: Inspect	Verify by: Demo.	Verification Signature	Description
✓	✓	✓CLS	Feature 1: Push button Start
✓	✓	✓CLS	Feature 2: Weight Container
✓	✓	✓CLS	Feature 3: Bottom Color Sensors
✓	✓	✓CLS	Feature 4: IR Sensor Arm
✓	✓	✓CLS	Feature 5: Short / Stationary Gripper Arm
✓	✓	✓CLS	Feature 6: Double Decker
o	o		Feature 7: Wheel Configuration
o	o		Feature 8:

(Attach additional pages if there are more features to be listed.)

Page 1 of 4

Figure 27-System Design Features Sign Off

ENGR 2620 – Integration II   Final Project

Team Number: 5   (Optional) Team Name: ____________

Integration II: Task - 1
Pickup-and-Place

Definitions:

Pickup – The payload holding mechanism must be able to safely hold the payload and safely remove the payload from the pickup pedestal as the system prepares to transport the payload.

Place – The payload holding mechanism must be able to safely "place" the payload on the placement pedestal and safely release its hold on the payload (i.e. the holding mechanism cannot be in contact with the payload).

Task-1 Performance Sign-off

(Verification Signature)		Date: ____
✓CLS	1st Complete Run Payload Size (circle): L S	Runtime: Not completed Payload Color (Circle): R B
____	2nd Complete Run Payload Size (circle): L S	Runtime: ____ Payload Color (Circle): R B

For partial Credit

(Initial)	Date: ____
✓CLS	System picks up payload
×	System determines payload color
✓CLS	System determines payload size
×	System finds correct path color.
×	System follows colored path toward the placement pedestal
✓CLS	System determines correct placement pedestal based on payload size
✓CLS	System places payload on the placement pedestal
N/A	No damage to payload during pickup, transport, and/or placement
____	Other: ____

Page 2 of 4

Figure 28-Task 1 Sign Off

Date: 5/26/2023

Integration II: Task - 2
Carry – { either Push or Pull } a Payload

Performance Sign-off

✓CLS Carry threshold achieved

Carry Objective Measurements

2kg	Weight	15°	Ramp Angle
0.5kg	Weight	20°	Ramp Angle
	Weight		Ramp Angle
	Weight		Ramp Angle

✓CLS (Circle Choice) Push Pull threshold achieved

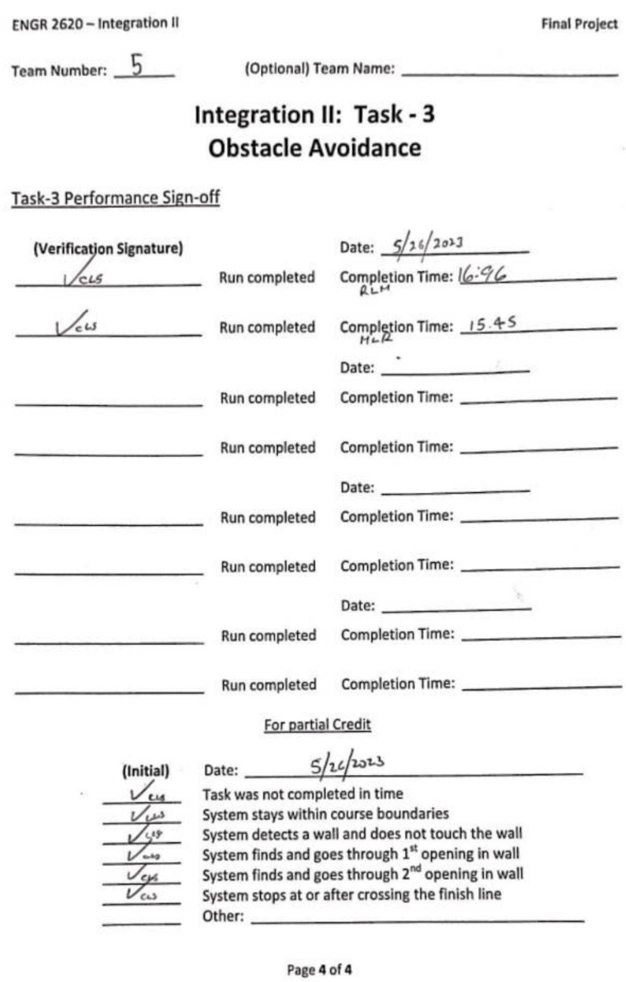
Push / Pull Objective Measurements

0.5kg	Weight	15°	Ramp Angle
	Weight		Ramp Angle
	Weight		Ramp Angle
	Weight		Ramp Angle

Comments:

Page 1 of 1

Figure 29-Task 2 Sign Off



ENGR 2620 – Integration II   Final Project

Team Number: 5   (Optional) Team Name: ______

Integration II: Task - 3
Obstacle Avoidance

Task-3 Performance Sign-off

(Verification Signature)		Date: 5/26/2023
✓CLS	Run completed	Completion Time: 16:96 RLM
✓CLS	Run completed	Completion Time: 15.45 MLR
		Date: ______
______	Run completed	Completion Time: ______
______	Run completed	Completion Time: ______
		Date: ______
______	Run completed	Completion Time: ______
______	Run completed	Completion Time: ______
		Date: ______
______	Run completed	Completion Time: ______
______	Run completed	Completion Time: ______

For partial Credit

(Initial)	Date: 5/26/2023
✓CLS	Task was not completed in time
✓CLS	System stays within course boundaries
✓CLS	System detects a wall and does not touch the wall
✓CLS	System finds and goes through 1st opening in wall
✓CLS	System finds and goes through 2nd opening in wall
✓CLS	System stops at or after crossing the finish line
______	Other: ______

Page 4 of 4

Figure 30-Task 3 Sign Off

Appendix C

Table 5-Allowed Hardware Components

Table 1. Allowed hardware components.

Hardware Components		
Component	**Qty**	**Link for more information**
Grid Plate 17 x 29 Hole	2	https://www.servocity.com/1116-series-grid-plate-17-x-29-hole-136-x-232mm/
U-Channel 1 Hole	6	https://www.servocity.com/1120-series-u-channel-1-hole-48mm-length/
2-Post Clamping Mount	4	https://www.servocity.com/1401-series-2-side-2-post-clamping-mount-43mm-width-22mm-bore/
Lightweight Set Screw Hub 4mm	4	https://www.servocity.com/1308-series-lightweight-set-screw-hub-4mm-bore/
Lightweight Set Screw Hub 6mm	2	https://www.servocity.com/1308-series-lightweight-set-screw-hub-6mm-bore/
Omni Wheel	4	https://www.servocity.com/3604-series-omni-wheel-14mm-bore-96mm-diameter/
Disc Wheel	4	https://www.servocity.com/3607-series-disc-wheel-14mm-bore-96mm-diameter-black-2-pack/
ServoBlock	2	https://www.servocity.com/servoblock-standard-size-25-tooth-spline-hub-shaft/
Round-End Pattern Plate 7 Hole	1	https://www.servocity.com/1105-series-round-end-pattern-plate-7-hole-176mm-length/
Round-End Pattern Plate 5 Hole	1	https://www.servocity.com/1105-series-round-end-pattern-plate-5-hole-128mm-length/
L-Channel 1 Hole	2	https://www.servocity.com/1113-series-l-channel-1-hole-48mm-length/
Parallel Gripper Kit A	1	https://www.servocity.com/parallel-gripper-kit-a/
Flanged Ball Bearing	4	https://www.servocity.com/1611-series-flanged-ball-bearing-6mm-id-x-14mm-od-5mm-thickness-2-pack/
Stainless Steel D Shaft	1	https://www.servocity.com/2101-series-stainless-steel-d-shaft-6mm-diameter-300mm-length/
26 or 116 RPM DC brushed Motors	4	https://www.servocity.com/26-rpm-premium-planetary-gear-motor/ https://www.servocity.com/116-rpm-premium-planetary-gear-motor/
High-torque servo motors	2	https://www.servocity.com/2000-series-dual-mode-servo-25-2/
High-speed servo motors	2	https://www.servocity.com/2000-series-dual-mode-servo-25-3-speed/

Table 6-Allowed Electronic Components

Table 2. Allowed electronic components.

Electronic Components		
Component	**Qty**	**Link for more information**
Teesny 4.1	2	https://www.pjrc.com/store/teensy41.html
USB cable type A and type B male	2	https://www.amazon.com/MaGeek-Samsung-Motorola-Android-Smartphones/dp/B00WMARA04/ref
Ultrasonic Module HC-SR04 Sensor	2	https://www.amazon.com/Dorhea-Ultrasonic-Distance-Duemilanove-Rapsberry/dp/B07L68X65N/ref
IR Obstacle Avoidance Sensor	2	https://www.amazon.com/HiLetgo-Infrared-Avoidance-Reflective-Photoelectric/dp/B07W97H2WS/ref
RGB Color Recognition Sensor	3	https://www.amazon.com/DEVMO-TCS3200-Recognition-Detector-Compatible/dp/B07Y88WRNQ/ref
Thin Film Pressure Sensor	2	https://www.amazon.com/Pressure-Precise-Force-Sensitive-Resistor-Resistance-type/dp/B07T1CHY58/ref
Rotary Angle Sensor	2	https://www.amazon.com/ACEIRMC-CJMCU-103-SV01A103AEA01R00-Trimmer-Potentiometer/dp/B094XT5WMS/ref
L298 7A motor controllers	2	https://www.amazon.com/Controller-Regulator-Industrial-Optocoupler-Isolation/dp/B0B8RL7PXM/ref
Buck Converter 12v to 5-7v	2	https://www.amazon.com/AITRIP-Mini360-Converter-Airplane-Step-Down/dp/B09MVK48KY/ref
12V DC Power Connector	1m 1f	https://www.amazon.com/Power-Connector-Female-Adapter-Camera/dp/B07C61434H/ref
TalentCell Rechargeable 12V	1	https://www.amazon.com/TalentCell-Rechargeable-12000mAh-Multi-led-indicator/dp/B00ME3ZH7C/ref
Wire Stripper, 20-30 AWG	1	https://www.amazon.com/Eclipse-CP-301G-ProsKit-Precision-Stripper/dp/B005IVIDIA/ref
Breadboard	4	https://www.amazon.com/Breadboard-Solderless-Prototype-Male-Female-Female-Female/dp/B073X7G71P/ref
PCB Solder able Breadboard	1	https://www.amazon.com/ELPZON-Solder-able-Breadboard-Electronics-Compatible/dp/B0B27XB69M/ref
Push button	2	
Thumb Joystick Module	2	https://www.amazon.com/Wishiot-Joystick-Controller-Breakout-Arduino/dp/B089VXPHDH/ref
Organizer box	2	https://www.amazon.com/DEVMO-TCS3200-Recognition-Detector-Compatible/dp/B07Y88WRNQ/ref