Senior Design - Final Report

Team 301
IEEE SoutheastCon 2022 Hardware Competition

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1. Disclaimer

Team 301 is not responsible for any injuries incurred while recreating or operating this design. This project is a scale model and is not intended for public use. The design was created with the very specific scenario of the IEEE SoutheastCon Hardware Competition in mind and would require significant design changes in order to be reproduced for a commercial purpose.

2. Acknowledgments

We would like to thank the Electrical & Computer Engineering department at the FAMU-FSU College of Engineering. They were our sponsor for our project and supplied the majority of our funding and resources. Furthermore, they gave us access to the senior design lab where tools were available for use that assisted us in the completion of our project. Namely, our professor, Dr. Oscar Chuy was our bridge to the department. He sent in all of our part orders, and made sure we received them in a timely manner. Dr. Chuy also taught us the necessary information to form the basis of some of our algorithms, like the PID controller and the line tracking.

We would like to also thank Dr. Bruce Harvey, who was our advisor for our project. Through his experience with past hardware competitions, and his engineering background, he helped us towards choosing viable solutions in various portions of our robot. Additionally, he gave us unrestricted access to his own private lab, which is larger than the senior design lab, has even more tools and resources, and was only used by us. This private space fostered better teamwork and focus.

We would also like to thank our classmate Justin Green and his father. They helped us solve a major issue that could have disabled our robot the day before the competition. Mr. Green gave us advice on how to solve a power issue that was causing our microcontrollers to restart. The advice allowed us to pinpoint the cause of the issue, and allowed us to not only solve the problem but also improve the power delivery. Justin also gave us similar advice, as well as a component from his own project that was key to the robot returning to a functional state. Without them, we could have not gotten our robot to run the day of the competition.

Finally, we would like to thank the hardware team from UNC Charlotte. At the competition while preparing our robot, we found we had misplaced our solder, and they let us use as much of theirs as we needed. Additionally, we were having issues employing a connection solution in which we needed to solder directly to our motor driver, instead of using the default screw terminals. A member of their team volunteered to help us out, and used their soldering iron with a more suitable tip, to create a solid connection. UNC Charlotte went on to win the competition, and we congratulate them on their technical abilities and good sportsmanship.

3. Abstract

The annual IEEE SoutheastCon Hardware Competition is a robotics design contest. This year's competition is held in the birthplace of Mardi Gras, Mobile Alabama, and thus is Mardi Gras-themed. The competition tasks us with designing a small-scale model of a driverless parade float that follows a parade route, collects and throws beads, and pushes a marshmallow. Additionally, we can earn points by including a display and music that demonstrates our school spirit. Our display will be a screen with images of FSU's and FAMU's logos.

There are three rounds to the competition, with 10, 15, and 20 beads at each dowel, representing a tree, available for collection in each round. At the start of each round, our robot follows a painted line located in the center of the game board. Our robot stops at each tree to standby for collection of beads. Using a robotic arm, these beads are then collected and deposited into its catapult. Once the beads are collected, the robot continues along the parade route. Along the way, the robot uses image recognition to detect nets and then throw the beads into them. Each round will have one marshmallow on the board that represents a member of the crowd that is on the road. Points are earned for each bead collected and thrown into a net, for each marshmallow pushed into an alleyway, and for completing the course. Our goal is to have our robot finish the obstacle course while completing as many tasks as possible to maximize points.

Keywords: IEEE, SoutheastCon, Hardware, Competition, Robot

4. List of Tables

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6. Notation

IEEE	Institute of Electrical and Electronics Engineers
SoutheastCon	IEEE convention for the southeast region
PID	Proportional, Integral, Derivative
RAM	Random Access Memory
NiMH	Nickel Metal Hydride
IR	Infrared
COE	College of Engineering
LiDAR	Light Detection and Ranging
LiPO	Lithium Polymer
CAD	Computer-Aided Design
LCD	Liquid Crystal Display
PCB	Printed Circuit Board

7. Chapter One

7.1 Project Scope

Project Description:

Team 301's goal is to create a small form factor robot that can navigate and complete tasks within a course set up for the IEEE SoutheastCon 2022 Student Hardware competition. This robot will push, throw, and place items, while navigating the course in a timely manner, as described by the rules of the competition. The previously mentioned functionality will allow the robot to successfully participate in the competition and pursue victory for Team 301 and the FAMU-FSU College of Engineering.

Key Goals:

According to the rules of the competition, the robot must be able to perform the following tasks autonomously:

- Traverse an L-shaped track
- Push marshmallows off the track
- Retrieve beads from an elevated rack
- Launch said beads into fishnets placed along the outside of the track.
- Bonus points are awarded to Robots decorated with lights and music according to a chosen theme
- Complete the obstacle course in under 3-minutes, though the faster completed: the more points are awarded
- All of which also completed without straying from track or bumping into placed obstacles

Markets:

As the project is not for consumer or business use, there is no market. The project is exclusively for competition purposes as per the IEEE SoutheastCon 2022 Student Hardware rules.

Assumptions:

Team 301 will design a robot that abides by the rules and regulations of the IEEE SoutheastCon 2022 Student Hardware Competition to the best of their ability.

Stakeholders:

- FAMU-FSU College of Engineering
- Bruce Harvey, Ph.D.
- Oscar Chuy, Ph.D.
- Babak Noroozi, Ph.D.
- Jerris Hooker, Ph.D.

7.2 Customer Needs

No.	Need/Statement	Source
1	Adheres to competition specifications and rules	Rulebook
2	Pick up and throw/drop beads into fish nets and trash bins	Rulebook
3	Push the marshmallows off the roadway	Rulebook
4	Have a display that moves mechanically and lights up	Rulebook
5	Play a song	Rulebook
6	Complete the track in both directions	Rulebook

Table 1 - Need Statements

No.	Need	Requirement/Interpretation
1	1	Fit within 1’x1’x1’ at start
2	1	Include a labeled start switch
3	1	Be autonomously operated
4	2	Include an arm/appendage or other launching/dropping mechanism
5	3	Include a mechanism to push the marshmallows
6	4	Include a digital screen with extendable mechanism
7	5	Include speakers with player
8	6	Robotic base that includes wheels, battery, actuators

Table 2 - Requirements derived from the need statements in Table 1

Since the team does not have a specific customer, customer needs are described based on the IEEE SoutheastCon 2022 Hardware Competitions rulebook. According to the rulebook, there are 10 different ways to get points, including throwing beads, pushing marshmallows, and playing a song. These methods to get points can be considered the “questions” for the project, and the different ways we can implement these methods can be considered the “requirement/interpretation”.

To summarize: Our robot's goal is to accrue the most amount of points possible, by picking up and throwing beads into fish nets and trash bins, pushing marshmallows off the track, including lights and a display, playing a song, and completing the track in both directions.

7.3 Functional Decomposition

The goal of the project is to build a robot to compete in the SoutheastCon Hardware Competition. The robot must perform a variety of tasks successfully in order to place highly in the competition. These tasks include: picking up/throwing beads, pushing marshmallows out of the way, completing a track in two directions that is littered with obstacles, playing a song, and having a display that moves mechanically/lights up. The following is a functional decomposition detailing all the modules that will be included in the robot in order to accomplish these tasks.

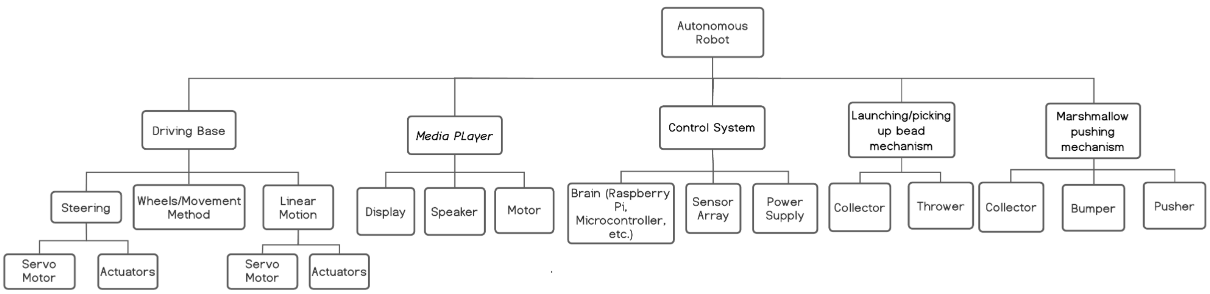


Figure 1 - Functional Decomposition

Level 0 of the design is composed of the Autonomous Robot Module, which describes the needed inputs of the robot such as the power switch, power supply, and the control module. The output would be the robot's movement, mechanisms, and media, which allow the robot to perform all the necessary functions at the SoutheastCon Hardware Competition. Level 1, the modules that would make all the functions of level 0 possible, would be composed of the Driving Base, Display/Media, Control System, Marshmallow Pushing Mechanism, and the Launching/Picking up Bead Mechanism modules. The Driving base uses servo motor and actuator data to output to the wheels and other movement mechanisms in order to move the robotic platform. The Display/Media module will take in data from an input storage device in order to output video and music on the display. The Control System will use the data sensor arrays to control all the general mechanisms and overall functionality. Both the Marshmallow Pushing Mechanism and Launching/Picking up Bead Mechanism use the sensors to complete their tasks of pushing and placing/launching their respective objects toward their destination, the specific mechanisms are still to be determined.

7.4 Target Summary

Based on the methods described in the *Tools to Validate Design* and *Derivation of Targets/Metrics* sections, we established these 10 targets that are related to our functions and requirements of the robot. The more targets we can accomplish, the more points are made available for us during the competition. The theoretical highest achievable score is ~141+number of marshmallows if all of our targets are met.

7.5 Concept Generation

100 Concepts

Crap Shoot

Brain
1. Arduino
2. Raspberry Pi
3. ATMEGA
4. MSP430
5. MSP432
6. BrainOS
7. Robot Operating System
8. FPLD/FPGA

Coding Languages
1. Python
2. C
3. C#
4. C++
5. Scratch
6. Raspberry OS
7. Java
8. JavaScript
9. VHDL

Wheels
1. Omni
2. Standard
3. Ball
4. Mecanum
5. Track
6. Caster

Linear Movement/Steering
1. Track the center line on the board
2. Track the barriers
3. Akerman Actuator
4. Model Predictive Controller
5. A* (A-Star)
6. Servo

Motors
1. Tiny Pager
2. Stepper
3. Linear
4. Brushed
5. Brushless
6. Spur Gear

Power Supply
1. Lead Battery
2. Lithium Battery
3. LiPo

Sensors
1. LiDAR
2. Sonar
3. Camera
4. Radar
5. Light
6. Proximity
7. Ultrasonic
8. Transmissive IR
9. Reflective IR
10. Gyroscope

Displays
1. iPod Touch
2. Multimedia Device
3. Android Tablet
4. Android Phone
5. Boosterpack LCD
6. Simple Circuit Speaker
7. Robotic accordion extender arm
8. Robotic joint that will fold

Bead Collectors
1. Fan Collector
2. Vacuum Collector
3. Arm Collector
4. Metronome style pusher and bin
5. Claw
6. probe
7. Fish Hook
8. Expandable Grappling Hook
9. Slide

Bead Storage
1. Retractable grate (if vacuum is used)
2. Container to Drop beads into until deposited
3. Container with trap door

Bead Launcher
1. Vacuum Launcher
2. Flywheel Launcher
3. Belt Launcher
4. Flywheel/Belt Combo Launcher
5. Slingshot

Marshmallow Mechanisms
1. Fan Pusher (angled fan blade)
2. Triangular Front Bumper
3. Moving extensions of walls Laterally
4. Moving extensions of walls Longitudinal
5. Mechanically rotating baskets
6. Accordion arm extender
7. Retractable motorized collector with sensor
8. No mechanism

Marshmallow Storage
1. Tube
2. Collector with reel
3. Bin
4. Net

Physical Base
1. Plywood
2. Aluminum sheet
3. Aluminum bead
4. (Other) Metal Corner Bead
5. Plastic

Attachment Methods
1. Glue
2. Screws
3. Velcro
4. Command strips
5. Nails
6. Bolts

Wiring
1. Copper wire
2. Silicone Cables
3. Polyurethane Cables
4. Polyvinyl Chloride (PVC) Cable
5. Solid
6. Stranded

Decorations

1. FAMU/FSU Colors
2. COE Colors
3. LED Lights
4. School Mascots

Connections
1. Solder
2. BreadBoard

Medium Fidelity

Concept 1

- Arduino
- C++
- Standard wheels
- Track the center line on the board
- Spur Gear Motor
- Lithium Battery
- Camera
- Multimedia Device
- Vacuum Collector
- Retractable grate
- Flywheel Launcher
- Fan Pusher (angled fan blade)
- Triangular Front Bumper

Concept 2

- Raspberry Pi
- C
- Omni
- Line tracking
- Brushless
- C Language
- LiPo Batteries
- Reflective IR
- Phone Display
- Vacuum Collector/Launcher
- Fan Pusher

Concept 3

- Raspberry Pi
- Python
- Omni
- Barrier Tracking
- Lidar
- Boosterpack LCD
- Vacuum with retractable grate
- Flywheel launcher
- Moving extensions of walls Longitudinal

Concept 4

- Brain - Arduino
- Coding Language - C++
- Wheels - Standard
- Linear Movement/Steering - Line and Barrier Tracking
- Motors - Brushed
- Power Supply - Lithium
- Sensors - IR
- Display - Android phone and Robotic accordion extender arm
- Bead Collector - Vacuum Collector
- Bead Launcher - Vacuum Launcher

Concept 5

- Brain - Raspberry Pi
- Coding Language - C++
- Wheels - Standard
- Linear Movement/Steering - Line and Barrier Tracking
- Motors - Brushed
- Power Supply - Lead Battery
- Sensors - Sonar and Camera
- Display - Boosterpack LCD
- Bead Collector - Fish Hook
- Bead Launcher - Slingshot

High Fidelity

Concept 6

- Raspberry Pi 4
- C
- 2 Standard Wheels, 1 Caster
- Center Line Tracking
- Barrier Tracking
- Brushless Motor
- LiPo Batteries
- LiDAR for Barriers
- Reflective IR for Line Tracking
- Camera for Net/Tree/Cup Detection
- Generic Screen
- Simple Circuit Speaker (may be included in generic screen)
- Folding Joint for Multimedia Display
- Fish Hook for Bead Collection
- Container to Store Beads Connected to Launching Mechanism
- Flywheel Launcher for Beads
- Fan to Collect Marshmallow
- No Storage - Drag it Along
- Aluminum Base
- Bolts for Attaching Base and Wheels, etc.
- Polyurethane Connection Cables
- COE Colors and Text
- Soldered Connections to Components
- Breadboard to Connect Components to Base

Concept 7

- Raspberry Pi 4
- Python
- Standard wheels with caster
- Line Tracking and Barrier Tracking
- Linear Motor
- Lithium battery
- LiDAR
- Multimedia Display with an accordion extender arm
- Vacuum Arm with a retractable grate and a flywheel Launcher
- Moving extensions of walls Longitudinal
- Aluminum Sheet
- Screws and bolts
- Copper Wiring
- COE Colors
- Solder

Concept 8

- Brain - Arduino Mega 2560
- Coding Language - C++
- Wheels - Standard(x2) and Caster(x1) for simple programming
- Linear Movement/Steering - Line and Barrier Tracking for tracking of the environment and the robots position
- Motors - Brushless for more efficient operation of the wheels
- Power Supply - Lithium
- Sensors - LiDAR , Camera and IR for environmental scanning and data collection
- Display and speaker - Android Phone and Robotic accordion extender arm
- Bead Collector - Vacuum Collector
- Bead Storage - Vacuum Collector container with door and grate
- Bead Launcher - Flywheel Launcher
- Marshmallow Mechanism - Triangular Bumper pushing marshmallow aside and Accordion arm extender with caster wheel to push marshmallow into the opening on the track
- Physical Base - Aluminum Sheet for lighter chassis
- Attachment Methods - Hot Glue and screws and bolts
- Wiring - Polyurethane Cables
- Decorations - COE Colors and Goose for school spirit
- Connections - Breadboard for ease of swapping out parts and soldering for parts that need to be soldered

7.6 Concept Selection

House of Quality

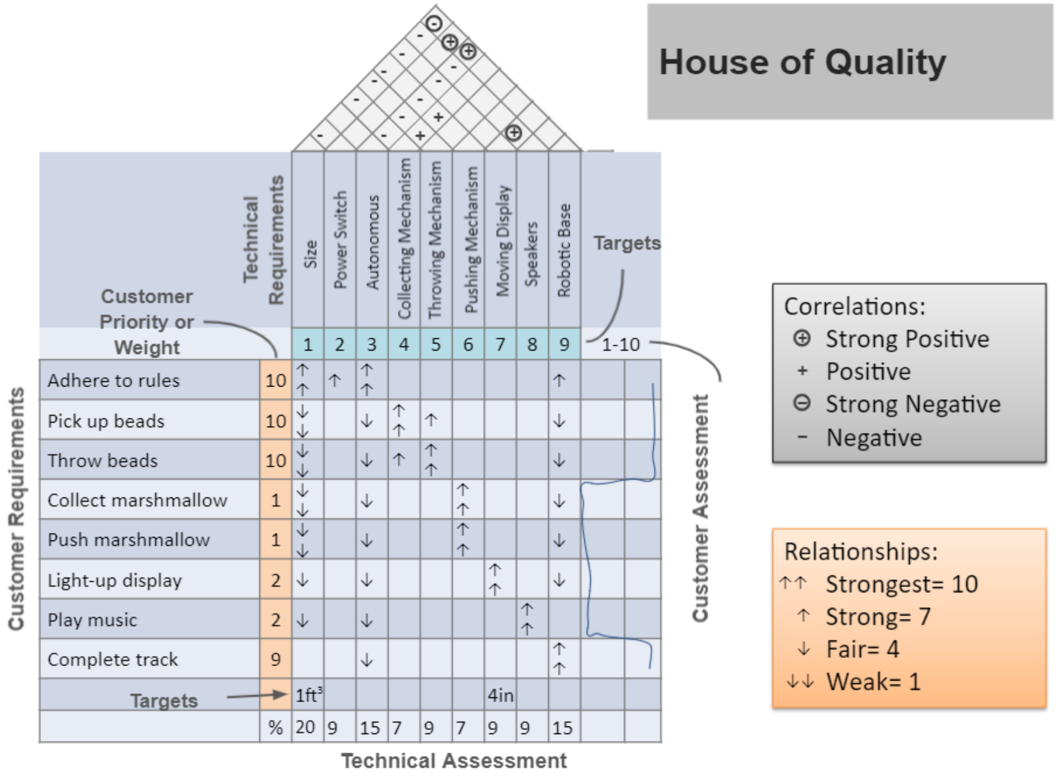


Figure 2 - House of Quality Diagram

The House of Quality chart gave us a visual and better understanding as to what technical requirements are worth the most to us. The Customer Requirement weights were decided in accordance to the amount of points awarded for completing the respective tasks. Additionally, the rules have to be followed, so they are worth a full 10 out of 10 weight. The correlations were decided based on how negatively or positively the requirements affect each other. Similarly, the relationships were decided based on how negatively or positively the customer requirements (needs) affect the technical requirements. The final percentages (Technical Assessment), were decided based on an equation we created. We took the positive arrows minus the negative arrows for each category. Then we subtracted this number from ten. This gave us a total of 93% when adding all the weights. To increase clarity on what we think is more important on the design, we bumped the size requirement to 20% (since it is absolutely required), bumped the robotic base to 15% (to match the autonomy), and increased the throwing mechanism to 9% (to distinguish the importance over the collecting of beads and the marshmallow mechanism). From these results, we believe that the level of importance of each requirement is as follows:
Size > Autonomy > Robotic Base > Power Switch > Throwing Mechanism > Moving Display > Speakers > Collecting Mechanism > Pushing Mechanism.
One thing to note with our final values, is that in order to launch our beads, we need to collect them. So, the effective importance for mechanisms related to beads is 16%. Since we do not have competitors, our customer assessment is a visual representation of the need’s priorities.

AHP Tables

Brain	Weight	Arduino	Raspberry Pi	MSP430	MSP432	FPLD/FPGA
Accuracy	0.64	2	4	2	3	5
Ease of Implementation	0.26	3	5	4	4	1
Cost	0.1	4	4	5	3	1
Score		2.46	4.26	2.82	3.26	3.56

Table 3 - AHP for the Microprocessor/Microcomputer

The Raspberry Pi is the best brain choice because of its ease of use and its accuracy, which was based on its RAM, frequency, and pin count.

Coding Language	Weight	Python	C	C#	C++	Scratch	RaspberryOS	Java	JavaScript	VHDL
Accuracy	0.64	8	9	6	9	3	7	5	5	4
Ease of Implementation	0.26	8	9	2	8	1	8	5	6	2
Cost	0.1	0	0	0	0	0	0	0	0	0
Score		7.2	8.1	4.36	7.84	2.18	6.56	4.5	4.76	3.08

Table 4 - AHP for the Primary Coding Language.

C is the best coding language to use because of its direct interface with hardware and because of the team's familiarity with the language.

Wheels	Weight	Omni	Standard	Ball	Mecanum	Track
Accuracy	0.64	5	3	5	5	1
Ease of Implementation	0.26	2	5	1	2	4
Cost	0.1	1	5	1	1	1
Score		3.82	3.72	3.56	3.82	1.78

Table 5 - AHP for the Wheels

Although the omni wheels scored the highest, we settled on standard wheels due to their simple construction and movement method.

Navigation	Weight	Track center line	Track Barriers	Model Predictive	A*
Accuracy	0.64	5	5	4	6
Ease of Implementation	0.26	6	5	4	3
Cost	0.1	6	5	4	3
Score		5.36	5	4	4.92

Table 6 - AHP for the Navigation

Line tracking was selected for maintaining orientation on the track because of the simple programming required.

Motors	Weight	Tiny Pager	Stepper	Linear	Brushed	Brushless	Spur Gear
Accuracy	0.64	2	6	1	4	5	3
Ease of Implementation	0.26	1	5	1	6	6	5
Cost	0.1	6	3	1	5	2	4
Score		2.14	5.44	1	4.62	4.96	3.62

Table 7 - AHP for the Motors

Although the stepper motor scored the highest, we decided on the brushless motors because of their high performance and low power draw.

Power Supply	Weight	Lead	Lithium	LiPo	NiMH
Accuracy	0.64	2	3	1	4
Ease of Implementation	0.26	1	2	3	4
Cost	0.1	2	1	3	4
Score		1.74	2.54	1.72	4

Table 8 - AHP for the Power Supply

An NiMH battery will be employed because of their abundance, ease of charging, and high efficiency.

Sensors	Weight	LiDAR	Sonar	Camera	Radar	Light	Ultrasonic	Transmissive IR	Reflective IR	Gyroscope
Accuracy	0.64	9	1	7	1	1	5	8	6	3
Ease of Implementation	0.26	4	1	3	1	5	1	9	9	2
Cost	0.1	1	8	2	3	7	9	5	9	4
Score		6.9	1.7	5.46	1.2	2.64	4.36	7.96	7.08	2.84

Table 9 - AHP for the Sensors

Transmissive IR will be used for barrier detection, but we will also be using cameras to identify the bead receptacles such as the nets and red solo cups.

Displays	Weight	iPod Touch	Multimedia D.	Android Tablet	Android Phone	LCD	Circuit Speaker	Accordion Arm	Folding Joint
Accuracy	0.64	5	8	7	6	6	8	8	6
Ease of Implementation	0.26	4	8	4	4	6	7	8	8
Cost	0.1	7	5	6	1	8	8	6	7
Score		4.94	7.7	6.12	4.98	6.2	7.74	7.8	6.62

Table 10 - AHP for the Display

A multimedia device will be attached to a motor of some sort that will move the device rotationally 4+ inches.

Bead Collector	Weight	Fan	Vacuum	Arm	Claw	Fish Hook	Grappling Hook	Slide
Accuracy	0.64	6	7	9	8	6	7	3
Ease of Implementation	0.26	2	4	5	6	8	7	9
Cost	0.1	7	2	1	3	8	6	9
Score		5.06	5.72	7.16	6.98	6.72	6.9	5.16

Table 11 - AHP for the Bead Collector

We will be using a robotic arm to collect the beads from the trees due to the high level of accuracy.

Bead Storage	Weight	Retractable Grate	Tub	Tub w/ Door
Accuracy	0.64	2	1	3
Ease of Implementation	0.26	1	3	2
Cost	0.1	2	3	2
Score		1.74	1.72	2.64

Table 12 - AHP for the Bead Storage.

With our proposed design, we decided bead storage will not be necessary, and the beads will just be held by the arm until they are thrown.

Bead Launcher	Weight	Vacuum	Flywheel	Flywheel/Belt	Slingshot	Arm
Accuracy	0.64	1	3	4	2	5
Ease of Implementation	0.26	5	4	3	3	4
Cost	0.1	4	3	3	5	2
Score		2.34	3.26	3.64	2.56	4.44

Table 13 - AHP for the Bead Launcher

Although the arm scored the highest for its launching capabilities, we decided on using a flywheel mechanism to eliminate the need for a storage area.

Marshmallow Mech.	Weight	Angled Fan Blade	Triangle Bumper	Moving walls Lat.	Moving walls Lon.	Rotating Baskets	Accordian Arm	None	Retractable motorized collector w/ sensor
Accuracy	0.64	4	2	6	6	4	7	1	8
Ease of Implementation	0.26	6	7	2	2	6	3	8	1
Cost	0.1	6	4	2	2	6	6	8	1
Score		4.72	3.5	4.56	4.56	4.72	5.86	3.52	5.48

Table 14 - AHP for the Marshmallow Mechanism

To push the marshmallows from the roadway, we will be using an arm that extends out linearly, with a rotatable cup that fits around the marshmallow to push it along.

Marshmallow storage	Weight	Tube	Reel	Bin	Net
Accuracy	0.64	1	4	2	4
Ease of Implementation	0.26	1	2	1	4
Cost	0.1	3	1	4	4
Score		1.2	3.18	1.94	4

Table 15 - AHP for the Marshmallow storage

To store the marshmallows, we found a net that simply drags it along is the best choice due to its simplicity and ease of implementation. However, we have decided to use a more static cup design that emulates a net.

Base	Weight	Plywood	Aluminum Sheet	Aluminum Bead	Plastic	Metal Corner Bead
Accuracy	0.64	3	5	4	1	4
Ease of Implementation	0.26	5	5	5	5	5
Cost	0.1	4	3	5	4	5
Score		3.62	4.8	4.36	2.34	4.36

Table 16 - AHP for the Base

The aluminum sheet was chosen for its sturdiness, light weight, and cost.

Attachment	Weight	Glue	Screws	Velcro	Command	Nails	Bolts
Accuracy	0.64	1	5	2	2	5	5
Ease of Implementation	0.26	5	5	5	5	5	5
Cost	0.1	5	4	5	5	4	4
Score		2.44	4.9	3.08	3.08	4.9	4.9

Table 17 - AHP for the Attachment

The screws, nails and bolts were chosen due to their simplicity when it comes to implementing, as well as their strength and cost, however, we are also likely to use glue, velcro, and command strips in our build, depending on the component placement.

Wiring	Weight	Copper	Silicone Cables	Polyurethane	Polyvinyl Chloride	Solid	Stranded
Accuracy	0.64	5	6	6	4	5	4
Ease of Implementation	0.26	4	5	6	4	4	5
Cost	0.1	6	2	5	2	1	2
Score		4.84	5.34	5.9	3.8	4.34	4.06

Table 18 - AHP for the Wiring

Polyurethane cabling will be used because of their low cost, and we already have access to an abundance of them.

Decor	Weight	FAMU/FSU Colors	COE Colors	LED Lights	Mascots
Accuracy	0.64	4	4	1	4
Ease of Implementation	0.26	3	4	1	3
Cost	0.1	4	4	1	4
Score		3.74	4	1	3.74

Table 19 - AHP for the Decor

The COE colors were chosen to represent both institutions, while keeping a consistent color scheme. It would also be easier to implement than LED Lights or the Mascots since those would take space on the robot.

Connections	Weight	Solder	Breadboard
Accuracy	0.64	2	1
Ease of Implementation	0.26	1	2
Cost	0.1	1	2
Score		1.64	1.36

Table 20 - AHP for the Connections

Soldering was chosen for its ability to create a secure attachment between the components and the devices. However, a breadboard will be implemented into our final design as well, as it allows for certain components to be easily swappable, in case there is a faulty component.

The following table was used to determine the importance of cost, ease of implementation, and accuracy. In the AHP tables, the weights are translated directly and can be seen as percent importance. Each concept was then rated against each other from 1 to the number of concepts in the category. The higher the ranking, the better the concept. The score is the summation of the concept rank times the weight of the category. The highest scores gave us the theoretical best concept.

	Cost	Ease of Implementation	Accuracy	Geometric Mean	Weights
Cost	1	0.3333333333	0.2	0.405480133	0.104729434
Ease of Implementation	3	1	0.33333333	0.9999999967	0.2582849937
Accuracy	5	3	1	2.466212074	0.6369855723
				Results sorted:	Weights
Scale of importance:	1 = Equal	3 = Moderate	5 = Strong	Accuracy	0.64
				Ease of Implementation	0.26
				Cost	0.1

Table 21 - AHP

Pugh Selection Matrix

The following matrix compares the concepts listed in section 7.5.

Pugh Chart 1

Criteria	Weight	Option 1	Option 2	Option 3	Option 4 (Baseline)
Accuracy	0.64	-1	0	1	-
Ease of implementation	0.26	1	0	-1	-
Cost	0.1	1	0	-1	-
Score		-0.28	0	0.28	-
Continue?		No	Yes	Combine	Combine

Table 22 Pugh Chart 1 for Overall Design

Pugh Chart 2

Criteria	Weight	Option 2	Combination	AHP
Accuracy	0.64	-1	1	-
Ease of implementation	0.26	-1	1	-
Cost	0.1	0	1	-
Score		-0.9	1	-
Continue?		No	Yes	-

Table 23 Pugh Chart 2 for Overall Design

The Pugh chart gave insight to the whole design of the robot and how the components worked together in each category. We thoroughly analyzed and compared each component to the AHP results and tallied up which designs had the most desirable components for each category to fill in the Pugh charts. Based on the first chart we decided to not use option 1 as it had the worst ranking due to the lack of accuracy. We decided to combine option 3 and its high accuracy with our AHP design, which used the top components in each AHP category. This combination method led us to our final design which is discussed below.

Final Concept

- Brain - Raspberry pi
- Coding Language - C
- *Wheels - Standard(x2) and Caster(x1) for simple programming
- *Linear Movement/Steering - Line and Barrier Tracking for tracking of the environment and the robots position
- *Motors - Brushless for more efficient operation of the wheels
- Power Supply - NiMH
- Sensors - camera, transmissive IR for environmental scanning and data collection
- Display and speaker - Multimedia device and rotating arm
- Bead Collector - Arm
- Bead Storage - Arm
- Bead Launcher - Flywheel
- Marshmallow Mechanism - Accordion arm w cup
- *Physical Base - Aluminum Sheet for lighter chassis
- Attachment Methods - screws and bolts
- Wiring - Polyurethane Cables
- Decorations - COE Colors for school spirit
- Connections - Breadboard for ease of swapping out parts and soldering for parts that need to be soldered

The final design is based on a combination between our third high fidelity concept and the best concepts found from our AHP tables. We also made minor tweaks based on the team's familiarity with certain components and concepts. The robot will use the Raspberry Pi while using C and it will be based on a three-wheeled system: two powered and one passive caster. It will employ both line and barrier tracking and will use a camera and transmissive IR. Brushless motors will be used for Stanmovement. A NiMH RC-car battery will be used for power delivery. An arm will be used in conjunction with a flywheel launcher to collect and throw the beads. An accordion with a small cup will be used to move and push the marshmallow. An aluminum sheet will be used as the physical base along with screws and bolts. Polyurethane cables will be used to connect the battery and boards together. The robot will be decorated in blue to represent the College of Engineering's spirit. This final design appears to give us the best shot at victory at the competition.

7.7 Spring Project Plan

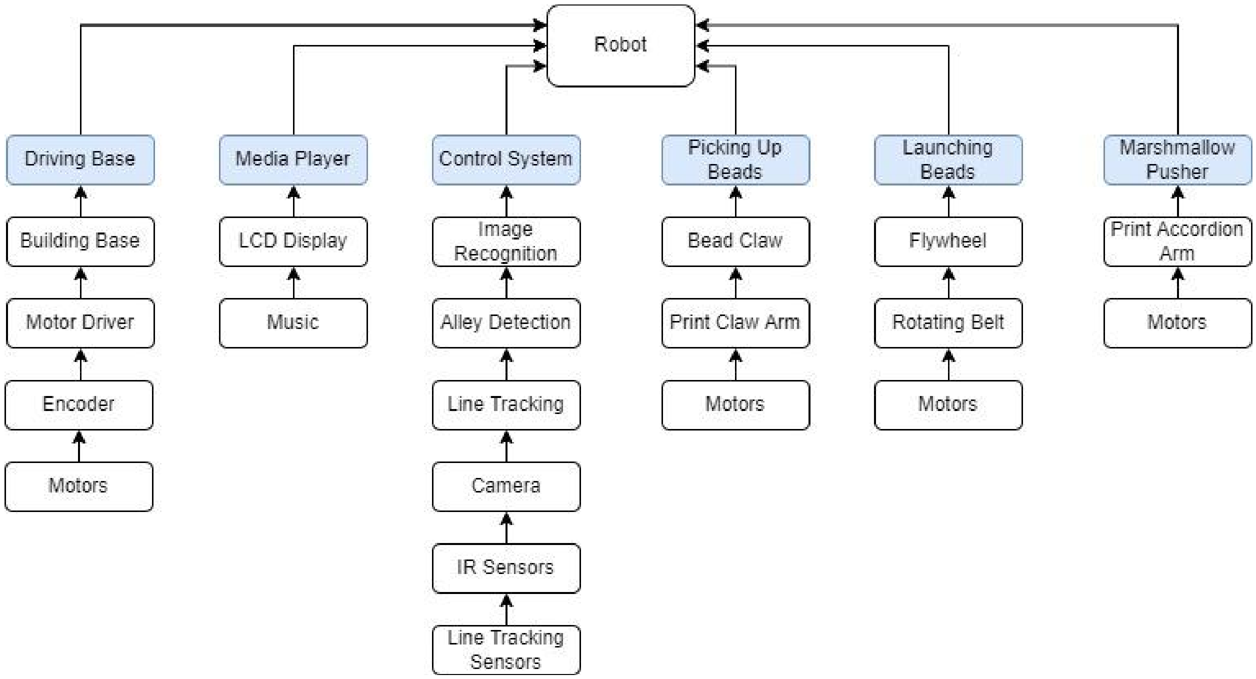


Figure 3 - Work Breakdown Structure

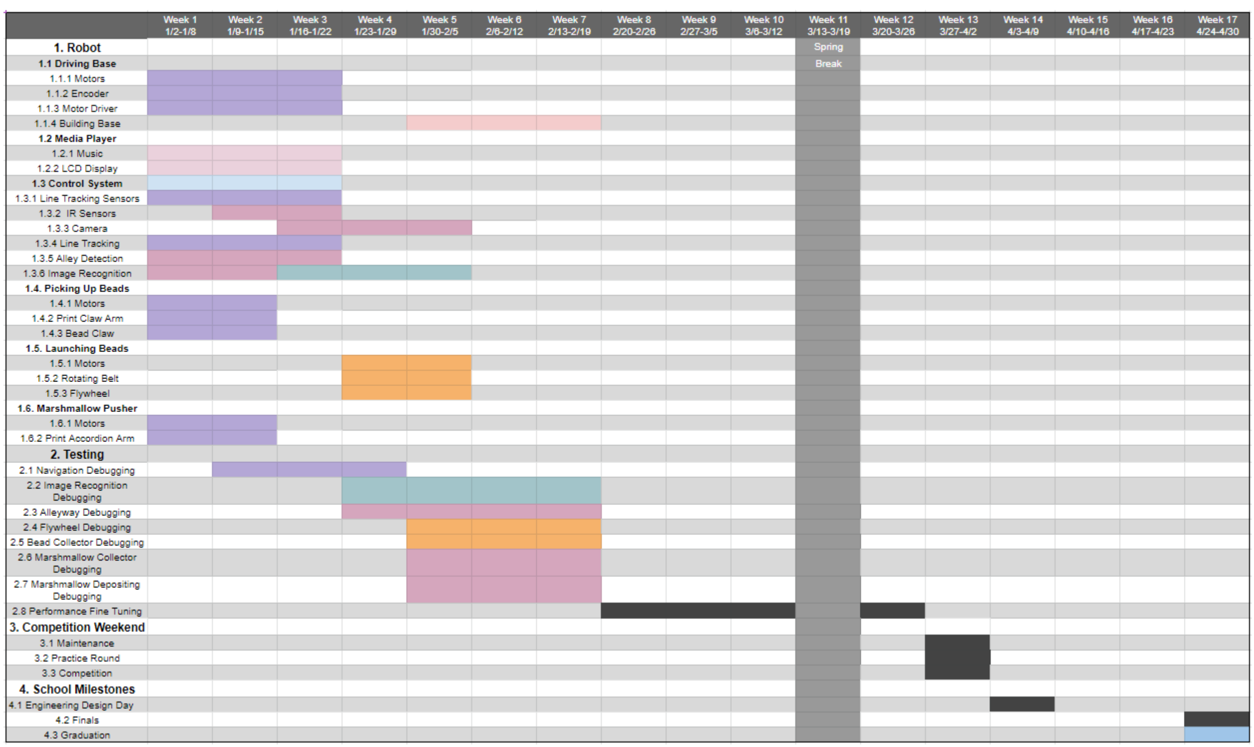


Figure 4 - Gantt Chart

8. Chapter Two

8.1 Restated Project Definition and Scope

Project Description:

Team 301's goal is to create a small form factor robot that can navigate and complete tasks within a course set up for the IEEE SoutheastCon 2022 Student Hardware competition. This robot will push, throw, and place items, while navigating the course in a timely manner, as described by the rules of the competition. The previously mentioned functionality will allow the robot to successfully participate in the competition and pursue victory for Team 301 and the FAMU-FSU College of Engineering.

Key Goals:

According to the rules of the competition, the robot must be able to perform the following tasks autonomously:

- Traverse an L-shaped track
- Push marshmallows off the track
- Retrieve beads from an elevated rack
- Launch said beads into fishnets placed along the outside of the track.
- Bonus points are awarded to Robots decorated with lights and music according to a chosen theme
- Complete the obstacle course in under 3-minutes
- All of which also completed without straying from track or bumping into placed obstacles

Markets:

As the project is not for consumer or business use, there is no market. The project is exclusively for competition purposes as per the IEEE SoutheastCon 2022 Student Hardware rules.

Assumptions:

Team 301 will design a robot that abides by the rules and regulations of the IEEE SoutheastCon 2022 Student Hardware Competition to the best of their ability.

Stakeholders:

- FAMU-FSU College of Engineering
- Bruce Harvey, Ph.D.
- Oscar Chuy, Ph.D.
- Babak Noroozi, Ph.D.
- Jerris Hooker, Ph.D.

8.2 Detailed Design

I. Selected Concept

- Brain: Raspberry pi
- Coding Language: C
- Wheels: Standard(x2) and Caster(x1) for simple programming
- Linear Movement/Steering: Line and Barrier Tracking for tracking of the environment and the robots position
- Motors: Brushless for more efficient operation of the wheels
- Power Supply: NiMH
- Sensors: camera, transmissive IR for environmental scanning and data collection
- Display and sound: Display and speaker
- Bead Collector: Arm
- Bead Storage: Arm
- Bead Launcher: Flywheel
- Marshmallow Mechanism: Accordion arm w cup
- Physical Base: Aluminum Sheet for lighter chassis
- Attachment Methods: screws and bolts
- Wiring: Polyurethane Cables
- Decorations: COE Colors for school spirit
- Connections: Breadboard for ease of swapping out parts and soldering for parts that need to be soldered

II. Design Revisions

The selected concept was derived from thorough comparisons of the high fidelity designs. The analysis and comparison was done using a variety of methods including House of quality charts, AHP/ PUGH tables, etc.. The resulting selected design is therefore a combination of the best qualities of all three high fidelity concepts.

The overall design went through many revisions from the initial selected concept to the final design. The discussed revisions first go over the structural changes and the changes of the components and systems. These changes were made in the process of testing and integration. While assembling the robot, major design flaws became clear and these changes reflect the solutions to problems encountered.

The first major change to the design was making the base round instead of square. This change would allow the robot to turn in place within the small track without making contact with the barriers. With this change the robot also needed a second caster wheel for stability. The second large design change involved increasing the size of the robot by adding a raised platform in order to add more components to the robot. To reduce the amount of complex mechanisms and due to a rule change within the competition rules, the marshmallow mechanism was changed and instead replaced with a passive bumper that prevents the marshmallow from getting run over and instead pushes it onto the side of the track. The final structural revision was the change from a metallic base to 3D printed bases made from Polylactic Acid (PLA). This change made our robot much lighter as well as made the design much more customizable, allowing for holes and indents to be printed to accommodate the components.

One of the most important changes was the removal of the Raspberry Pi and the Pi camera and replacing them with Arduino Mega 2560 and a PixyCam. This change simplified the image recognition process by using pre-made image training software instead of having to create and train an image recognition algorithm. The loss of the Raspberry Pi meant that we also lost the ability to play music on the robot since Arduinos are not well suited to playing music. A revision made through the initial stages of the development of the robot was using the Arduino for the navigation algorithm, drivetrain functions, and sensor controls. This was done in order to take advantage of its real-time operation, making the system simpler and more responsive than its implementation within the Raspberry Pi would have been. The brushless motors were swapped for brushed ones since the slightly higher efficiency of the brushless motors did not warrant the cost. The flywheel launcher was removed in favor of a simpler catapult that could simultaneously store the collected beads. The final large revision is the removal of IR sensors within the design. The reliability of the IR sensors was not good enough to justify their use, therefore the robot's navigation relied solely on line tracking in the final design.

III. Final Detailed Design

- Microprocessor: Arduino Mega(x2) and Arduino UNO
- Coding Language: C++17
- Wheels: Standard(x2) and Caster(x2)
- Steering: Line tracking robots position
- Motors: Brushed DC electric motor(x2)
- Power Supply: NiMH
- Sensors: PixyCam and line sensors(x7)
- Display: LCD display
- Bead Collector: Arm
- Bead Storage: Catapult
- Bead Launcher: Catapult
- Marshmallow Mechanism: Front bumper
- Physical Base: 3D printed two-tier base

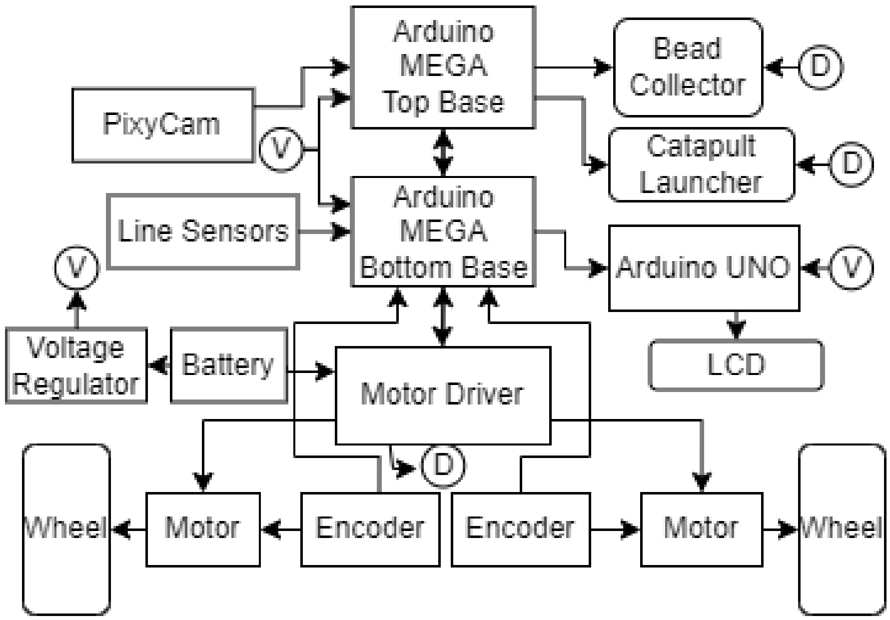


Figure 5. - Final Detailed Design

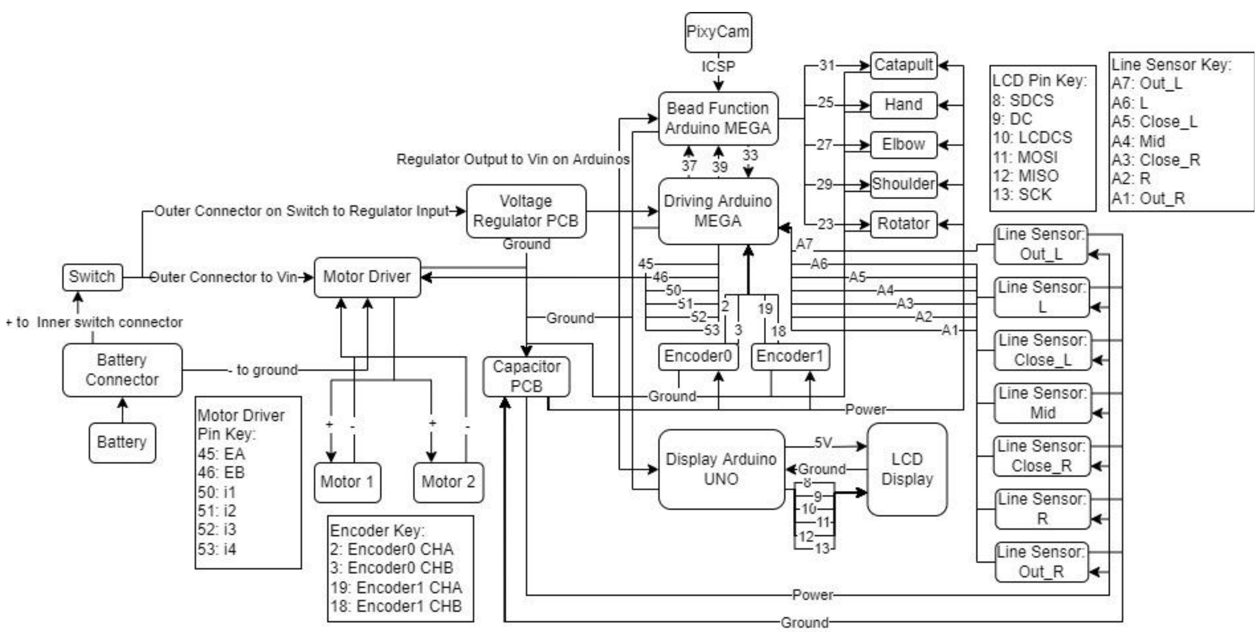


Figure 6. - Wiring Diagram

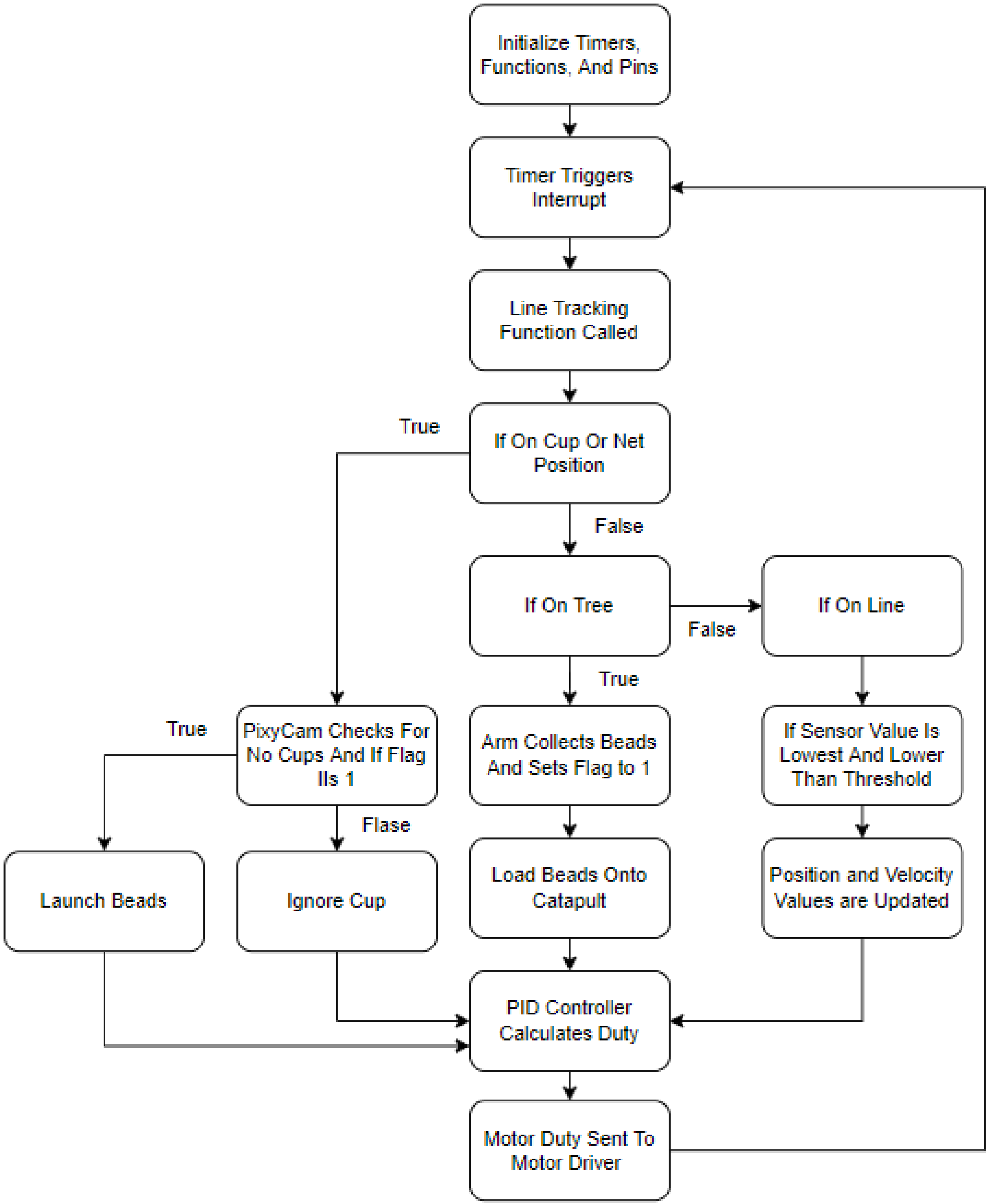


Figure 7. - Code Block Diagram

8.3 Testing & Validation

Test Writer: Melissa Emery						
Test Case Name		LCD Test			Test ID #:	1
Description		Functionality Test			Type:	Unit
Tester Information						
Name of Tester		Melissa Emery			Date	1/7/22
Hardware/Software Ver.		1.5			Time	5:33 PM
Setup		Run developer graphics test and modify to include FAMU-FSU Logo				
Step	**Actions**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Run Graphics Test	Display will run test successfully and to completion to verify functionality of the LCD Screen	x			Screen functions as it should.
2	Run Example code	Example code with example image from SD-Card breakout displays successfully	x			SD-Card Breakout works and communication with Arduino is well-established.
3	Replace example image with school logo	School Logo displays correctly	x			Logo displays reliably on power up.
Overall Test Result			x			LCD working properly

<table>
<tr><td colspan="7">Test Writer: Raymond Martinez</td></tr>
<tr><td colspan="2">Test Case Name</td><td colspan="3">Launcher Testing</td><td>Test ID #:</td><td>2</td></tr>
<tr><td colspan="2">Description</td><td colspan="3">Launcher design revisions in order to improve capability to launch beads.</td><td>Type</td><td>Unit</td></tr>
<tr><td colspan="7">Tester Information:</td></tr>
<tr><td colspan="2">Name of Tester</td><td colspan="3">Raymond Martinez</td><td>Date</td><td>1/14/22</td></tr>
<tr><td colspan="2">Hardware/Software Ver.</td><td colspan="3">3.0</td><td>Time</td><td>6:00pm</td></tr>
<tr><td colspan="2">Setup</td><td colspan="5">Treadmill design: 3d printed holding case for four bearings for two cylinders, placed two belts on the cylinder and tension, and then drill in the holding cases on a wooden boards and insert a motor into one of the cylinders to spin it and the belts.
Catapult design: 3d print a catapult arm with bucket and base, then place it within the base, put a screw in the arm to hold a spring and attach the other end to a servo motor that will tension the spring and cause a launch.</td></tr>
<tr><td>Step</td><td>Actions</td><td>Expected Results</td><td>Pass</td><td>Fail</td><td>N/A</td><td>Comments</td></tr>
<tr><td>1</td><td>Assembled a treadmill with wood, belt, and DC motors</td><td>Launch beads a foot distance at minimum</td><td></td><td>x</td><td></td><td>Did not launch the required distance due to lack of friction with beads</td></tr>
<tr><td>2</td><td>3d printed catapult with spring and servo motor</td><td>Launch beads a foot distance at minimum</td><td>x</td><td></td><td></td><td>Launched the required distance but was not large enough to carry many beads</td></tr>
<tr><td>3</td><td>3d printed larger catapult with spring and servo motor</td><td>Launch beads a foot distance at minimum and hold many beads</td><td>x</td><td></td><td></td><td>Launched the required distance but was not large enough to carry many beads</td></tr>
<tr><td colspan="3">Overall Test Result</td><td>x</td><td></td><td></td><td>Can launch and carry beads without issue!</td></tr>
</table>

Test Writer: Melissa Emery			
Test Case Name	Marshmallow Test	Test ID #:	3
Description	Test for different pushing mechanisms	Type	Unit
Tester Information			
Name of Tester	Kelvin Hamilton	Date	1/20/22
Hardware/Software Ver.	2.0	Time	4:00 PM
Setup	3D Print two prototypes including an accordion/scissor arm and a rounded bumper		

Step	**Actions**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Attach a motor to one side of the scissor arm and rotating pin to the other. Connect the pin and motor.	When the motor is turned on, the rotating pin will push and pull the scissor arm open and closed.	x			Although functional, high accuracy of pin-pointing the marshmallow would be required.
2	Attach the rounded bumper to the front of the robot and drive forward into the marshmallow.	The marshmallow will be pushed off to the side out of the way of the robot.		x		Marshmallow gets pushed most of the way but occasionally gets caught on the wheels.
3	Add cardboard panels to the ends of the bumper to shield the tires from the marshmallow.	The marshmallow will be pushed off to the side out of the way of the robot.	x			A cost-effective solution to the problem mentioned in step 2.
Overall Test Result			x			Success

Test Writer: Destiny Law			
Test Case Name	Collector Testing	Test ID #:	4
Description	Revisions to collector mechanism to ensure collection of beads	Type	Unit
Tester Information			
Name of Tester	Kelvin Hamilton	Date	3/11/22
Hardware/Software Ver.	5.0	Time	11:00AM
Setup	3D print an arm and attach the claw horizontally and vertically. Attach the servo motors to the top base Arduino MEGA and attach it to the arm.		

Step	**Actions**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Mechanical arm with vertical claw	Arm will be able to pick up at least 3 beads		X		Due to the claw angle and the line tracking, the arm misses the tree and beads entirely. The arm drops heavily to the top base because the claw is too heavy.
2	Connect a spring to the top and bottom part of the arm to counteract the weight of the arm after bead collection	The arm will not fall heavily onto the top base of the robot	X			The arm does not drop onto the top base, but the claw only grabs 1-2 beads.
3	Mechanical arm with spring & horizontal claw	Arm is projected to pick up 3 or more beads.	X			
Overall Test Result			X			The arm successfully collected 3 or more beads and did not drop down onto the top base.

Test Writer: Raymond Martinez						
Test Case Name		Line Tracking Sensors Placement			Test ID #:	5
Description		Testing line sensor placement for optimal line tracking			Type	Debugging
Tester Information						
Name of Tester		Raymond Martinez			Date	3/11/22
Hardware/Software Ver.		3.0			Time	1:15pm
Setup		Line tracking sensors placed horizontally under the robot and connected by the analog pins to the analog pins on the Arduino MEGA 2560 on the bottom base				

Step	**Actions**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Placed in a straight line in between motors and front caster	See the line without issue	x			Followed the line well without much issue
2	Placed along front of bumper, spaced out in a V shape	See and follow line without issue		x		Large gaps between sensors would cause large inaccuracies
3	Placed in a straight line under the front bumper with a custom mount	See and follow line without issue	x			Followed the line without much issue and turned smoother due to larger lookahead distance
Overall Test Result			x			

Test Writer: Allison Rosenbaum			
Test Case Name	PixyCam	Test ID #:	6
Description	Image Recognition Test	Type	Unit
Tester Information			
Name of Tester	Melissa Emery	Date	3/18/22
Hardware/Software Ver.	2.0	Time	4:00
Setup	Run the PixyCam test code and implement to communicate with the top arduino when to execute the bead launcher sequence		

Step	**Actions**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Download the PixyCam Test code and train it to recognize the cups	It will show the red solo cup with a box labeling it			x	Although it recognized the cup, it would label anything with red undertones
2	Test with the white background	It will only have the label on the red solo cup	x			As long as the PixyCam is angled down, it won't mistake something red for the cup
3	Implement for the test run to only shoot when there isn't a cup in fixed locations	The robot will only launch the beads when there isn't a cup at locations that are hard coded into the robot	x			Worked very well recognizing when and when not to shoot
Overall Test Result			x			Overall successful

Test Writer: Raymond Martinez						
Test Case Name	Line tracking algorithm				Test ID #:	7
Description	Forming the best line tracking algorithm for the robots navigation				Type	Debugging
Tester Information:						
Name of Tester	Raymond Martinez and Kelvin Hamilton				Date	4/1/22
Hardware/Software Ver.	4.0				Time	11:40pm
Setup	Line tracking code testing and implementation on the Arduino MEGA 2560					

Step	Actions	Expected Results	Pass	Fail	N/A	Comments
1	Wrote navigation algorithm based on case statements with color thresholds	Track line and adjust the robot position for turns		x		While it worked on a floor with flat colors, the reflectivity of the paint made this method ineffective
2	Wrote navigation algorithm based on case statements with the color smallest value under the threshold	Track line and adjust the robot position for turns		x		While it did line track, the algorithm would fail on the initial all white start point
3	Previously written algorithm with an initial set distance moved to leave start point and also an automatic turnaround hardcoded into the end of the track	Track line, track positions, and adjust the robot position for turns	x			Works as intended, with few expected inaccuracies
4	Added objective locations for the robot to perform actions	Track line, track positions, adjust the robot position for turns	x			Works as intended, with few expected inaccuracies
Overall Test Result			x			

Test Writer: Raymond Martinez						
Test Case Name		Arm and catapult algorithm			Test ID #:	8
Description		Forming the best line tracking algorithm for the robots navigation			Type	Debugging
Tester Information:						
Name of Tester		Kelvin Hamilton			Date	4/2/22
Hardware/Software Ver.		2.0			Time	9:00am
Setup		Arm movement and catapult launching code testing and implementation on the Arduino MEGA 2560				
Step	**Actions**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Programmed the arm to grab, deposit, and hold down the catapult, and launched the catapult	Picked up the beads from tree locations, placed them into the catapult, held down the catapult, and launch	x			Worked well but would keep launching when catapult was empty
2	Added a check for launch prevention once catapult was empty	Picked up the beads from tree locations, placed them into the catapult, held down the catapult, and launched. Checks the catapult for beads before launching	x			Works as intended
Overall Test Result			x			

Test Writer: Allison Rosenbaum			
Test Case Name	Integrated Test	Test ID #:	9
Description	Full test runs on practice game board	Type	Integration
Tester Information			
Name of Tester	Team 301	Date	4/2/22
Hardware/Software Ver.	12.0	Time	9:00AM
Setup	Once each module is finished and working together, test on the completed practice board		

Step	**Actions**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Complete Practice run 1	Able to effectively complete each obstacle		x		The robot has power issues where different modules cannot work effectively together
2	Add a voltage regulator	The robot is able to complete the course without any modules failing due to power	x			Power was stabilized. Has an issue delivering power to the motor driver.
3	Soldered the voltage and ground directly to the motor driver	The robot consistent is able to complete the course without power issues for the motors	x			Fixed the power issue. The hard coded locations are now off.
4	Update the location for all the trees and net/cup placements	The robot is able to stop at accurate locations to collect or launch the beads	x			Stops at accurate locations. After the turnaround, it won't end back on the line.
5	Edit the code for the spin to make it more accurate	Is able to identify the line again more consistently	x			Found the line again more accurately.
6	Edit the code to grab multiple times to get more beads or	The robot is able to grab more beads			x	Although it worked, we could not implement it with the time constraint
7	Edit the code to only shoot for the first net after a tree	It will ignore a net if it's the second one after a tree, will reset after each tree	x			Worked Effectively
Overall Test Result			x			Robot was able to complete each obstacle

8.4 Results

Our robot was able to complete the track, collect and throw beads, push a marshmallow, and operate autonomously with a relatively low margin of error when operating on the intended track. Team 301 placed 12th place out of 33 at the IEEE SoutheastCon 2022 Hardware Competition.

8.5 Discussion

The robot was able to perform as necessary during the practice testing at the competition, however, during the competition rounds, the robot failed to complete certain tasks which cost the team a higher placement at the competition. The main point of failure on our competition runs was the turn around at the end of the board, which the robot failed to do in two out of three runs on the board, and got stuck after it on the third. It was a problem that was fixed after the second run, but due to some unknown margin of error, failed again during our last competition run. During the final run, the robot got stuck and tried to make up for the friction it encountered on the track when it gave the motors too much power and completely missed the line, causing it to get stuck. Nevertheless, the robot did successfully make it through part of the course using the line tracking algorithm, making stops and turns wherever they were necessary. The bumper, arm, and catapult also performed as they should have, with the image recognition functioning without any error.

The robot operated well within the intended environment, i.e. the robot tracks at the competition. The robot underperforms when it runs on surfaces not intended for operation without recalibration of the line sensors and the reworking of the actions performed at different positions. This underperformance is due to the highly specialized nature of our project and the requirements our robot needed to fulfill.

8.6 Conclusion

Our multi-disciplinary team built the robot from the ground up using engineering methods and techniques acquired from the senior design class and previous classwork. The objectives of the robot were met and the robot competed successfully.

8.7 Future Work

For future work, the robot can be used as a prototype for a life-sized Mardi Gras parade float. Significant changes would have to be made in order to adapt the design to function on other roads with less-distinctive markers. The final version of the design relies heavily on the consistency of the track that was provided by the competition. Paint hue, bystanders, and building colors are all factors that when changed along the parade route, the parade float would malfunction.

8.8 References

- IEEE SoutheastCon 2022 Student Hardware Competition rulebook

9. Appendix

9.1 Codes and Standards

The following points are the standards that are currently being used on the project and where. The application of our project to other scenarios is very limited, therefore there are only a few industry standards applied to our project.

- USB 3 Type A and Micro-USB

  This Universal Serial Bus 3 Type A and Micro-USB standards were implemented in the same cable on our design in several different ways. The first use of the standard was to transfer data from the coding software to flash the arduino boards with new code. The second use of the standards was that of powering the arduinos and the connected devices through the cord itself, in order to do testing when we did not yet possess a suitable power supply. The final use of the standard was when using the connection between the arduino and computer to monitor sensor values in order to amplify the accuracy of the algorithms.

  - USB 3 Type A
    - Combines USB 2.0 with the Superspeed bus. Transfer rate goes up to 5Gb/s
    - Used to communicate with Arduinos to modify code.
  - Micro-USB
    - Micro USB is a miniaturized version of the Universal Serial Bus (USB) interface developed for connecting compact and mobile devices such as smartphones, Mp3 players, GPS devices, photo printers and digital cameras.
    - Used to monitor and train PixyCam.
- C17

  The C17 version of C++ standard was primarily used in the Arduino IDE software to program several different functions into the Arduino boards that were used on the robot. Such functions include communicating with other Arduino boards, sending pulse width modulation signals to a motor driver, and processing data sent to the Arduino from the PixyCam. The standard was across three different boards: two Arduino Mega 2560's and an Arduino UNO.

  - The current ISO C++ standard is officially known as ISO *International Standard ISO/IEC 14882:2020(E) – Programming Language C++*.
  - Version of C used to program Arduino.
- Micro-SD

  Micro-SD was used to store data that was necessary for the acquisition of extra points within the competition. The card was to keep an image of the FAMU-FSU College of Engineering logo for the screen on the robot to access it at the command of the Arduino, with potential for more media, such as videos, to have been saved in the case that more media would need to be used. The card was lightweight and easy to install, which allowed for the robot to remain light and the interface simple to access without it getting in the way of other functions that the robot needed to perform.

- Flash memory card used to store long-term information
- Holds image for LCD Display

- OSHA electrical standards
    - A set of health standards that protect people exposed to dangers such as electric shock, electrocution, fires, and explosions
    - The team made sure to always have power off before making electrical design changes as well as sealing all exposed wires with electrical tape.
- IEEE C95.1-2019
    - Safety limits for the protection of persons against the established adverse health effects of exposures to electric, magnetic, and electromagnetic fields in the frequency range 0 Hz to 300 GHz are presented in this standard
    - The team made sure to always have power off before making electrical design changes as well as sealing all exposed wires with electrical tape.
- NESC
    - Published exclusively by IEEE and updated every 5 years to keep the Code up-to-date with changes in the industry and technology, the National Electrical Safety Code® (NESC®) sets the ground rules and guidelines for practical safeguarding of utility workers and the public during the installation, operation, and maintenance of electric supply, communication lines and associated equipment
    - The team made sure to always have power off before making electrical design changes as well as sealing all exposed wires with electrical tape.

9.2 Code of Conduct

Mission Statement

Team 301 is committed to ensuring a positive work environment that supports professionalism, integrity, respect, and trust. Every member of this team will contribute a full effort to the creation and maintenance of such an environment in order to bring out the best in all of us as well as this project.

Roles

Each team member is delegated a specific role based on their experience and skill sets and is responsible for all here-within (team members will assist in performing tasks of other team members should the need arise):

Team Members:

Project Manager [Kelvin Hamilton]

Manages the team as a whole; develops a plan and timeline for the project, delegates tasks among group members according to their skill sets; finalizes all documents and provides input on other positions where needed. The Project Manager is responsible for promoting synergy and increased teamwork. If a problem arises, the Project Manager will act in the best interest of the project. The Project Manager takes the lead in organizing, planning, and setting up meetings. The Project Manager will also assist the Project Analyst with the finances and will take on the role of Project Analyst should the current Project Analyst be unable to perform their duties. Finally, they give or facilitate presentations by individual team members and are responsible for overall project plans and progress.

Project Analyst [Melissa Emery]

Assists the Project Manager in maintaining the timeline and scheduling team meetings. They are responsible for keeping a record of all correspondence between the group and 'minutes' for the meetings. They are also responsible for managing the budget and maintaining a record of all purchase requests. Any product or expenditure requests must be presented to the Project Analyst, who is then responsible for reviewing and the analysis of equivalent/alternate solutions. They then relay the information to the team and if the request is granted, order the selection. A record of these analyses and budget adjustments must be kept. The Project Analyst will assume the role of Project Manager should the current Project Manager be unable to perform their duties.

Drivetrain Engineer [Raymond Martinez]

They are responsible for the design and programming of the drivetrain and related systems. They take initiative in deciding the physical components such as the wheels, motor drivers, etc. and program the necessary code to make the hardware function.They maintain a line of communication with all other members. They keep all design documentation for record. The Drivetrain Engineer is responsible for delegating tasks to other members as they pertain to Drivetrain.

Co-Drivetrain Engineer [Kelvin Hamilton]

They assist the Drivetrain Engineer as necessary to further progress the project. Hardware design choices are decided jointly between the Drivetrain and Co-Drivetrain Engineers. Should the Drivetrain Engineer be unable to perform their duties, the Co-Drivetrain Engineer will assume their responsibilities.

Data Acquisition Engineer [Allison Rosenbaum]

They are responsible for creating a program to process the information taken in from the IR sensors and the cameras. They are also responsible for the codebase for the robot. They maintain a line of communication with all other members. They keep all design documentation for record. Data Acquisition Engineer is responsible for delegating tasks to other team members as they pertain to sensors.

Peripheral Hardware Engineer [Allison Rosenbaum]
They are responsible for designing and programming the mechanisms needed for the various obstacles. They maintain a line of communication with all other members. They keep all design documentation for record. Peripheral Hardware Engineer is responsible for delegating tasks to other team members as they pertain to software.

Co-Data Acquisition Engineer [Destiny Law]
They assist the Data Acquisition Engineer as necessary to further progress the project. Software design choices are decided jointly between the Lead and Co-Data Acquisition Engineers. Should the Lead Data Acquisition Engineer be unable to perform their duties, the Co-Data Acquisition Engineer will assume their responsibilities.

Integration Engineer [Melissa Emery]
They are in charge of making sure the components of the project are cohesive and fit within the given parameters and scope of the project. The Integration Engineer will make sure that the final product will be rule abiding according to the given SoutheastCon Hardware Competition Rules. The Integration Engineer will be responsible for the development of the music and moving display on the robot and making sure that all modules communicate effectively. Should the Integration Engineer be unable to perform their duties, the lead Drivetrain Engineer will assume their responsibilities.

All Team Members:

- Work cooperatively on the overall project
- Buy into the project goals and success
- Deliver on commitments
- Adopt team spirit
- Listen and contribute constructively
- Be effective in trying to get message across
- Be open minded to others ideas
- Respect others roles and ideas

Communication

The main form of communication will be a GroupMe chat amongst the team, for non-formal communication (i.e. tasks, meeting dates, etc.). Email will be the secondary form of communication for formal discussions (i.e. advisor communication, file transfer, finances, etc.). A Google Drive shared amongst the team members will be the main form of document sharing. All members will have access to all files pertaining to the project but shall only edit those pertaining to their individual responsibilities (unless working closely with the team member in charge of said document).

Each group member must have a working email for the purposes of communication and file transference. Members must check their emails and GroupMe at least twice a day to check for important information and updates from the group. Although members will be initially informed via GroupMe, meeting dates and pertinent information from the advisor will be sent over email.

Responses to communication sent via Email/GroupMe are expected within 24 hours of being sent. If no response is received regarding important decisions, team members currently active in communication will vote to either extend communication again or make the decision without the unspoken party.

If a meeting must be canceled, an email/GroupMe must be sent to the group/advisor at least the day prior.

Attendance Policy

Any team member that cannot attend a meeting must give reasonable notice informing the group of their absence. Reason for absence will be appreciated but not required if personal. Repeated absences (3) in violation with this agreement will not be tolerated and will be reported to the course professor and team advisor. "Reasonable notice" will be determined by the Project Manager and the Project Analyst on a case-by-case basis.

Team Dynamics

The students will work as a team while allowing one another to feel free to make any suggestions or constructive criticism without fear of being ridiculed and/or embarrassed. If any member on this team finds a task to be too difficult it is expected that the member should ask for help from the other teammates. If any member of the team feels they are not being respected or taken seriously, that member must bring it to the attention of the team in order for the issue to be resolved. We shall NOT let emotions dictate our actions. Everything done is for the benefit of the project and together everyone achieves more.

Ethics

Team members are required to be familiar with the NSPE and IEEE Engineering Code of ethics. There will be stringent following of the NSPE and IEEE Engineering Code of Ethics. While there are no public, employer, or professional responsibilities, the codes must be upheld to ensure the safety and integrity of the team members, other competitors, and spectators.

Dress Code

Team and advisor meetings will be held in casual attire. Group presentations and the competition will be business casual with team shirts decided by the team.

Weekly and Biweekly Tasks/Meetings

All team members will participate in all meetings with the advisor. During said times: ideas, project progress, budget, conflicts, timelines, and due dates will be discussed. In addition, tasks will be delegated to team members during these meetings. Any team member not present in a pre-scheduled meeting forfeits their vote in decisions made during that meeting.

Tasks assigned during meetings are expected to have progress made by the next scheduled meeting or the task may be delegated to another team member.

Decision Making

It is conducted by consensus and majority of the team members. Should ethical/moral reasons be cited for dissenting reasons, then the ethics/morals shall be evaluated as a group and the majority will decide on the plan of action. Individuals with conflicts of interest should not participate in decision-making processes but do not need to announce said conflict. It is up to each individual to act ethically and for the interests of the group and the goals of the project. Achieving the goal of the project will be the top priority for each group member. Below are the steps to be followed for each decision-making process:

- Problem Definition – Define the problem and understand it. Discuss among the group.
- Tentative Solutions – Brainstorms possible solutions. Discuss among the group what is most plausible.
- Data/History Gathering and Analyses – Gather necessary data required for implementing Tentative Solution. Re-evaluate Tentative Solution for plausibility and effectiveness.
- Design – Design the Tentative Solution product and construct it. Re-evaluate for plausibility and effectiveness.
- Test and Simulation/Observation – Test design for Tentative Solution and gather data. Re-evaluate for plausibility and effectiveness.
- Final Evaluation – Evaluate the testing phase and determine its level of success. Decide if design can be improved and if time/budget allows for it.

Conflict Resolution

In the event of discord amongst team members the following steps shall be respectfully employed:

- Communication of points of interest from both parties which may include demonstration of active listening by both parties through paraphrasing or other tools acknowledging clear understanding.
- Administration of a vote, if needed, favoring majority rule.
- Project Manager intervention.
- Instructor will facilitate the resolution of conflicts.

Statement of Understanding

By signing this document the members of Team 301 agree to all of the above and will abide by the Code of Conduct set forth by the group.

Name	Signature	Date
Kelvin Hamilton		1/7/2022
Melissa Emery		1/7/2022
Allison Rosenbaum		1/7/2022
Raymond Martinez		1/7/2022
Destiny Law		1/7/2022

9.3 Functional Decomposition Charts

Cross-Reference Table

	Major Functions					
Minor Functions	Drivin g Base	Media Player	Control System	Launching/ Picking up Mechanism	Marshmallow Pushing Mechanism	Customer Needs
Steering	x		x	x	x	3,6
Wheels/Movement Method	x		x	x	x	3,6
Linear Movement	x		x			3,6
Display		x	x			4
Speaker		x	x			5
Media Player Motor		x	x			4
Brain	x	x	x	x	x	2,3,4,5,6
Sensor Array	x		x	x	x	2,3,6
Power Supply	x	x	x	x	x	2,3,4,5,6
Bead Collector			x	x		2
Bead Thrower			x	x		2
Marshmallow Collector			x		x	2
Marshmallow Bumper			x		x	3
Marshmallow Pusher			x		x	3

Table 24 - Cross Reference Table

Level 0:

Module	Autonomous robot
Inputs	Power supply, Power switch, Control Module (Microcontroller)
Outputs	Actuators, All Mechanisms, Display Media
Functionality	Move through the track automatically while collecting and throwing beads, removing marshmallows from the play area, playing a song, and displaying something on a moveable screen.

Table 25 - Overall Module

Level 1:

Module	Driving Base
Inputs	Steering Servo Motors and Actuators, Movement Servo Motors and Actuators
Outputs	Wheels or other movement mechanism (track, etc.)
Functionality	Move the robot through the course.

Table 26 - Driving Base Module

Module	Display/Media
Inputs	Media Storage Device (USB, SD Card, etc.), Control Module
Outputs	Display, Speakers, Motor Movement
Functionality	Lights up the display that moves mechanically and plays a song

Table 27. - Display/Media Module

Module	Control System
Inputs	Power Supply, Brain(raspberry pi), Sensor Array
Outputs	Controls all mechanisms
Functionality	Enables overall functionality

Table 28 - Control System Module

Module	Marshmallow Pushing Mechanism
Inputs	Sensors
Outputs	Robot pushing mechanism (TBD)
Functionality	Pushes the marshmallow in the sensed wall opening

Table 29 - Marshmallow Pushing Mechanism Module

Module	Launching/Picking up Bead Mechanism
Inputs	Sensors
Outputs	Mechanism to pick up/throw/place beads (TBD)
Functionality	Picks beads from “tree” and throws them into the nets and/or Drops them into trash bins

Table 30 - Launching/Picking up Bead Mechanism Module

9.4 Target Catalog

Fit within size regulation (not a function)

Metric: Box dimensions
Value: <= 1’ x 1’ x 1’
Justification: Needs to be within specified size limit to qualify for the competition
Importance: Critical
Methods of Validation: Fits in the size restriction box (1’ x 1’ x 1’)
Consequence of failure: Disqualification from the competition

Include a labeled start switch (not a function)

Metric: Switch Present
Value: Present or Not Present
Justification: Needed to shut off robot in case of emergency
Importance: Critical
Methods of Validation: The switch is clearly visible by judges
Consequence of failure: Disqualification from the competition

Be autonomously operated (not a function)

Metric: Hands free operation
Value: N/A
Justification:
Importance: Critical
Methods of Validation: Conducts all tasks independently
Consequence of failure: Disqualification from the competition

Collect beads from trees

Metric: Number of beads collected
Value: x potential based on if thrown or dropped
Justification: Needed to acquire beads
Importance: Moderate
Methods of Validation: Robot is able to reach out and collect beads
Consequence of failure: No points acquired
Corresponding Function: Launching/Picking Up Bead Mechanism

Throw beads into nets

Metric: Points per bead
Value: 2 per bead and 1 for each net used

Justification: Needed to throw beads for points
Importance: Moderate
Methods of Validation: Robot is able to throw beads into the nets from a distance without missing
Consequence of failure: No points acquired
Corresponding Function: Launching/Picking up Bead Mechanism

Drop beads into trash bins

Metric: Points per bead
Value: 1 for each bead and 1 per trash bin used
Justification: Needed to place beads for points
Importance: Moderate
Methods of Validation: Robot is able to drop beads into the cups without knocking the cups over
Consequence of failure: No points acquired
Corresponding Function: Launching/Picking up Bead Mechanism

Push the marshmallows

Metric: Points per marshmallow
Value: Unknown (1 for each marshmallow)
Justification: Needed for to push marshmallows into holes for points
Importance: Moderate
Methods of Validation: Robot is able to sense the marshmallows then push them off the track
Consequence of failure: No points acquired
Corresponding Function: Marshmallow Pushing Mechanism

Digital screen with extendable mechanism

Metric: Points for the extendable display
Value: 4
Justification: Shows school spirit and for points
Importance: Low
Methods of Validation: Screen can extend to at least 4" while lighting up and showing a display
Consequence of failure: No points acquired
Corresponding Function: Display/Media

Speakers with player

Metric: Points for playing a song
Value: 2
Justification: For points
Importance: Low
Methods of Validation: Songs are able to clearly be heard from the speakers once the robot is powered on
Consequence of failure: No points acquired
Corresponding Function: Display/Media

Complete the track (not tied to a function)

Metric: Points, Ability to complete the track in either direction
Value: 10
Justification: For points
Importance: Critical
Methods of Validation: Robot is able to maneuver the track without any accidents

Consequence of failure: Not qualified to participate in the competition

Metric No.	Need	Metric	Importance	Units	Marginal Value	Ideal Value
1	Fit within size regulation	Box dimensions	Critical	Feet	1 x 1 x 1	1 x 1 x 1
2	Include a labeled start switch	Switch Present	Critical	N/A	Present	Present
3	Be autonomously operated	Hands free operation	Critical	N/A	Present	Present
4	Mechanism to collect beads from trees	Number of beads collected	Moderate	Points per beads	2 (potential)	20, 30, 40 (per round, potential)
5	Mechanism to throw beads into nets	Points per bead	Moderate	Points per bead	2	20, 30, 40 (per round)
6	Mechanism to drop beads into trash bins	Points per bead	Moderate	Points per bead	1	10, 15, 20 (per round)
7	Mechanism to push the marshmallows	Points per marshmallow	Moderate	Points per Marshmallows	1	Unknown
8	Digital screen with extendable mechanism	Points for the extendable display	Low	Points	4	4
9	Speakers with player	Points for playing a song	Low	Points	2	2
10	Complete the track	Points, Ability to complete the track in either direction	Critical	Points	10	10

Table 31 - Target Table

9.5 Engineering Drawing

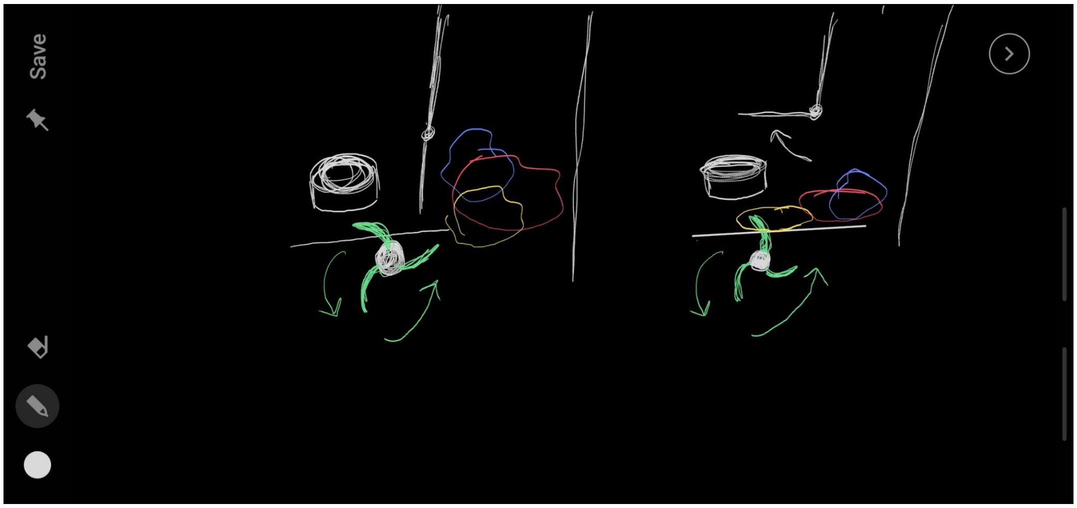


Figure 8. - Bead Detangling Solution Concept 1

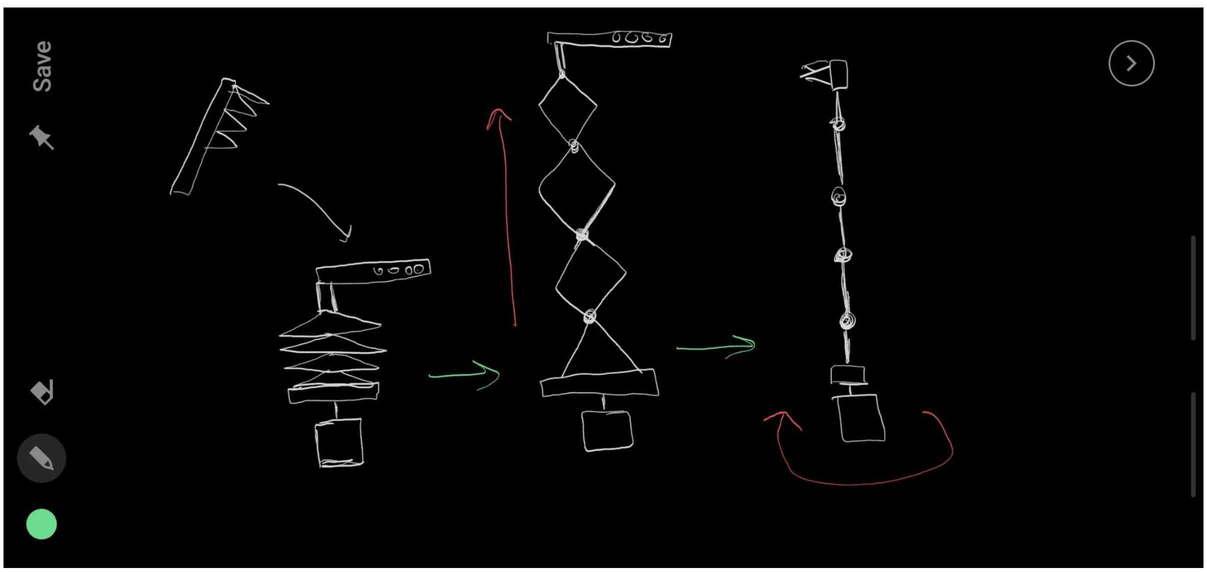


Figure 9. - Collector Scissor Arm Concept

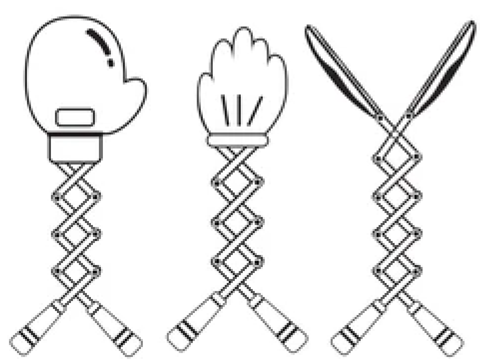


Figure 10. - Example of Scissor Arm for Marshmallow Mechanism

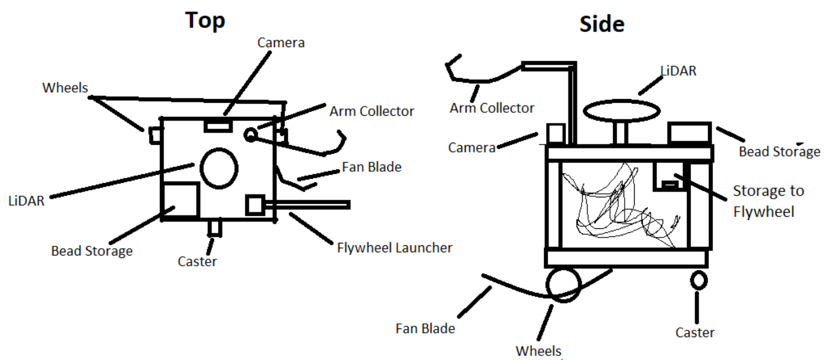


Figure 11. - High Fidelity Concept 1

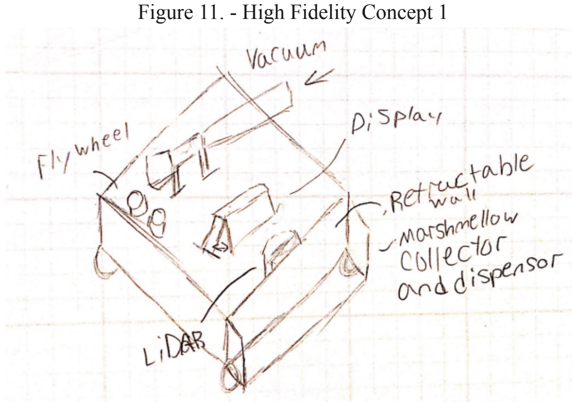


Figure 12. - High Fidelity Concept 2

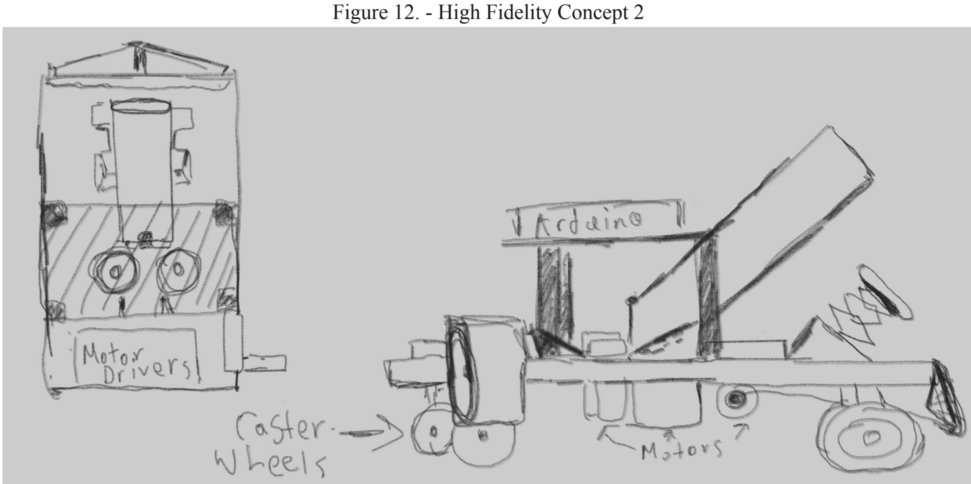


Figure 13. - High Fidelity Concept 3

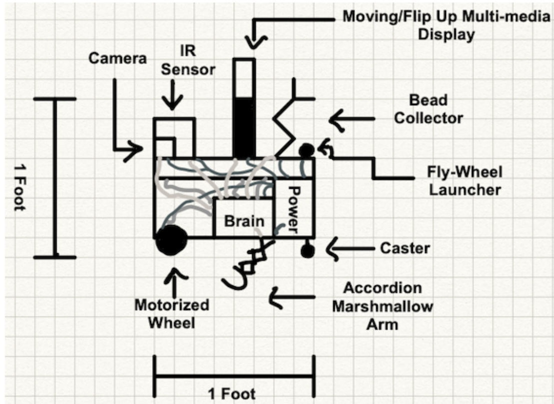
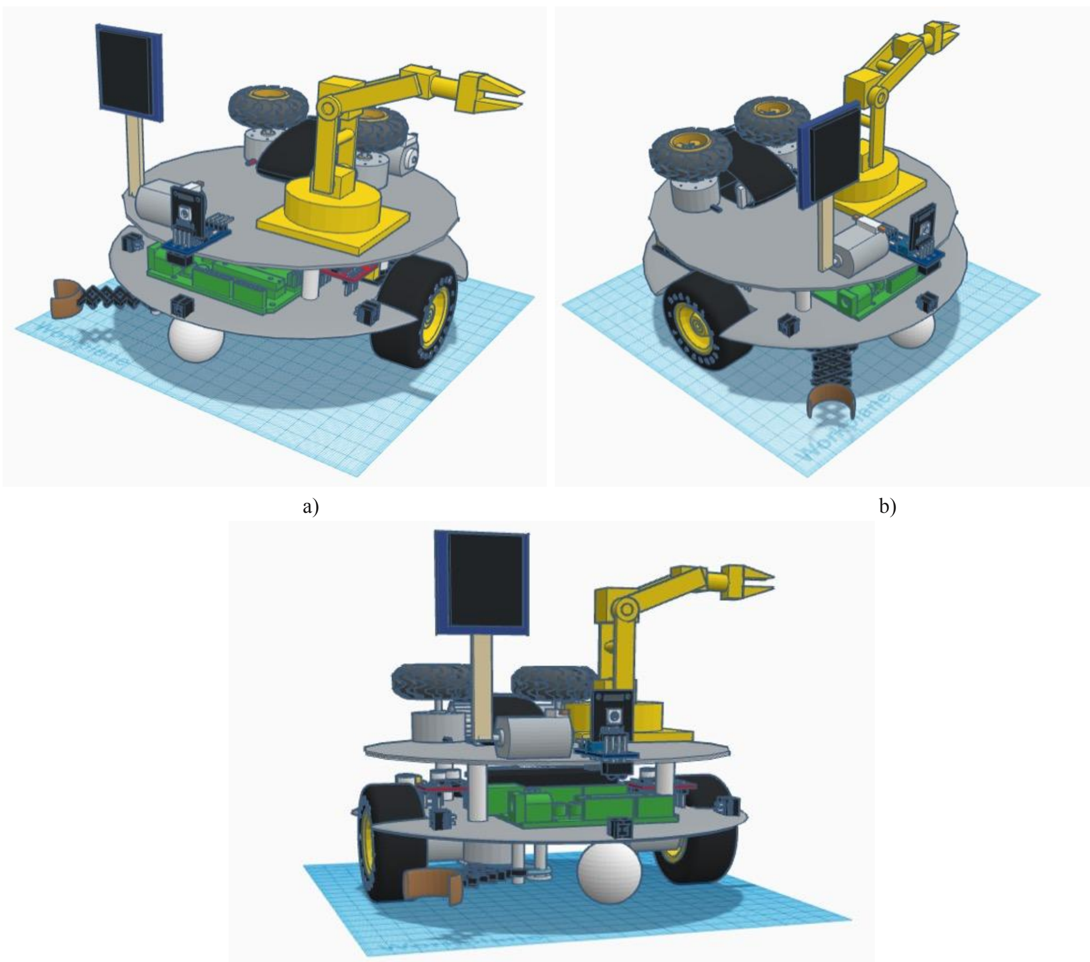


Figure 14. - Concept Selection



a) b)

c)

Figure 15. - CAD Diagrams of Preliminary Design
a) Top Right View b) Top Left View c) Front View

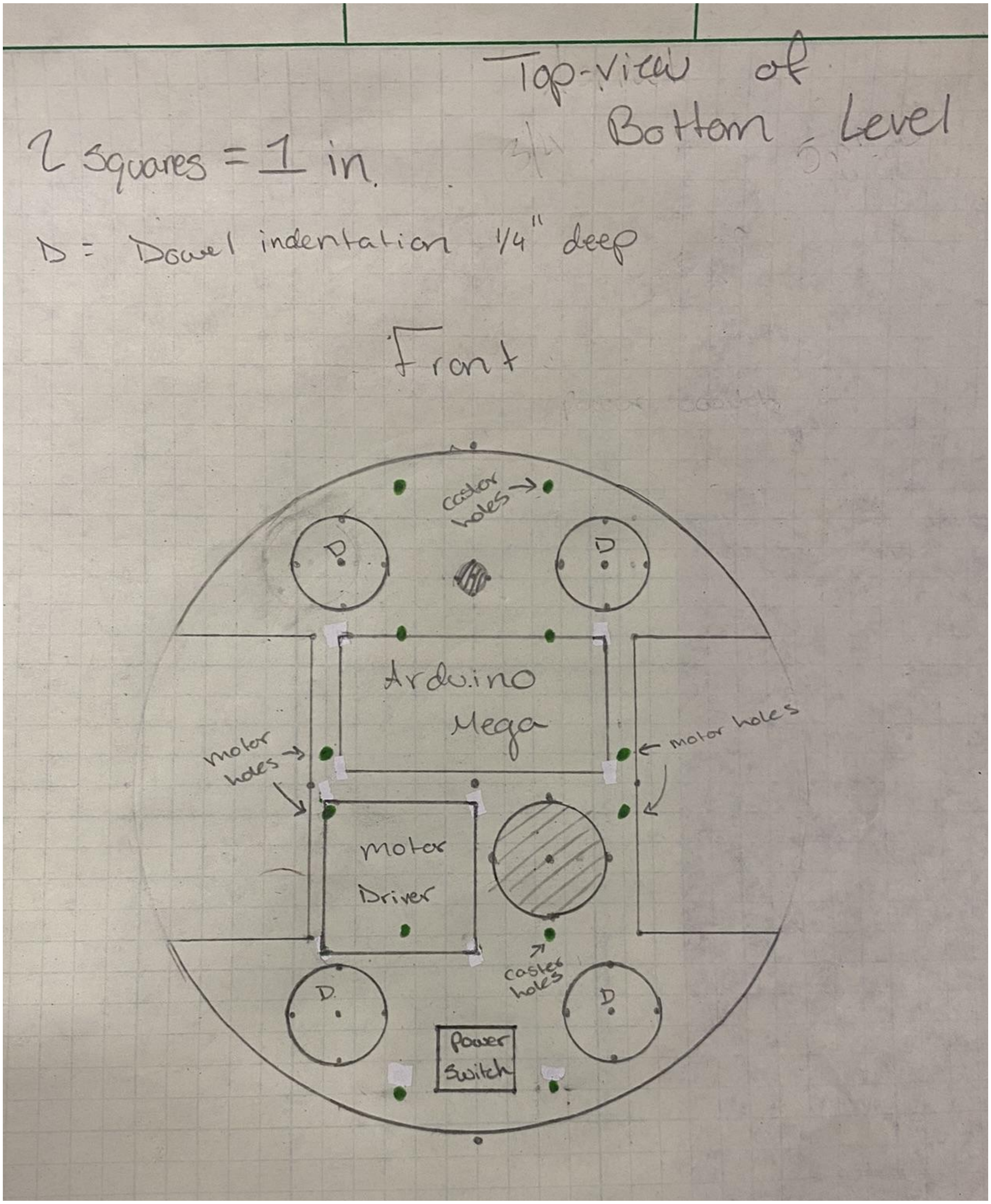


Figure 16. - Detailed Top View of Bottom Level

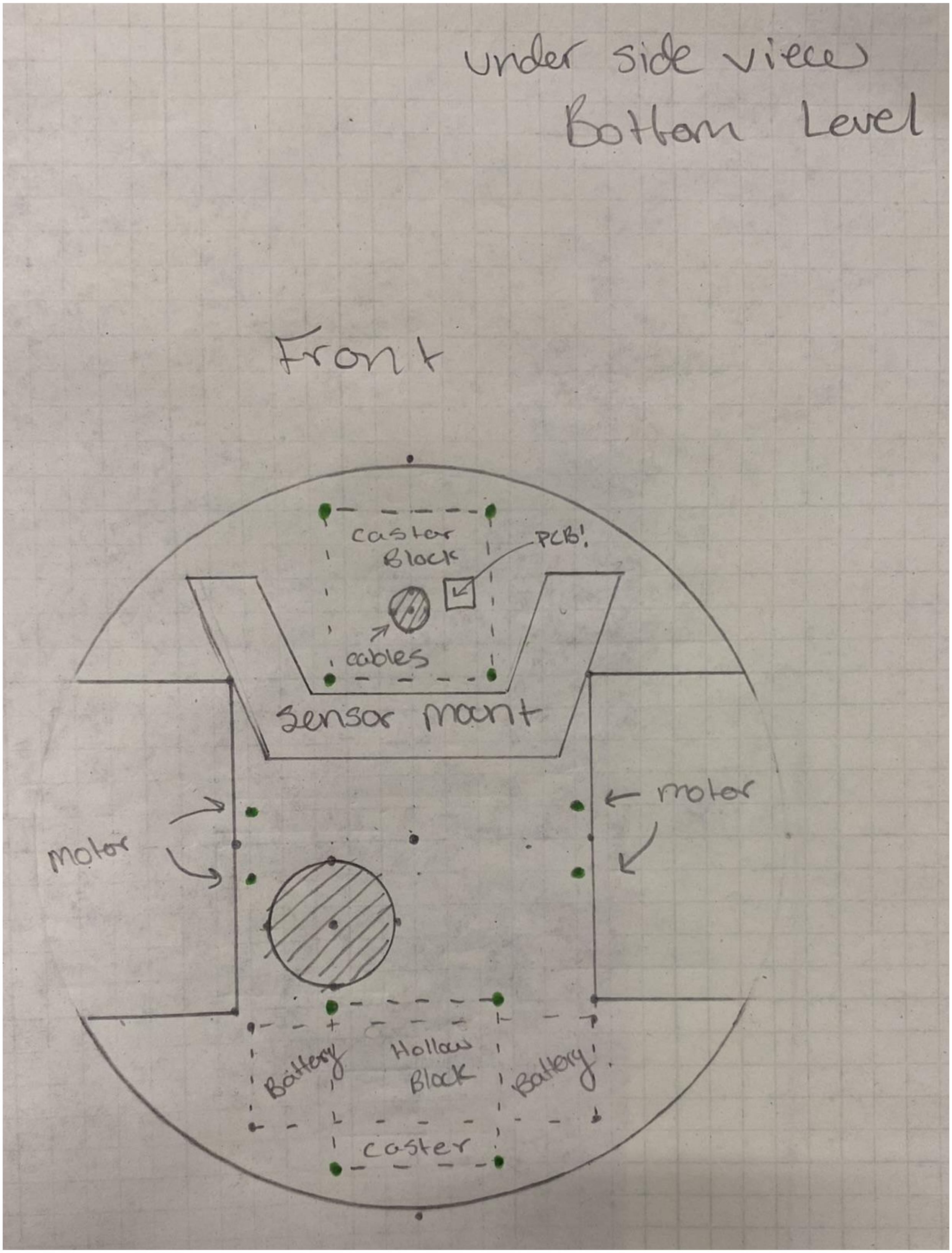


Figure 17. - Detailed Bottom View of Bottom Level

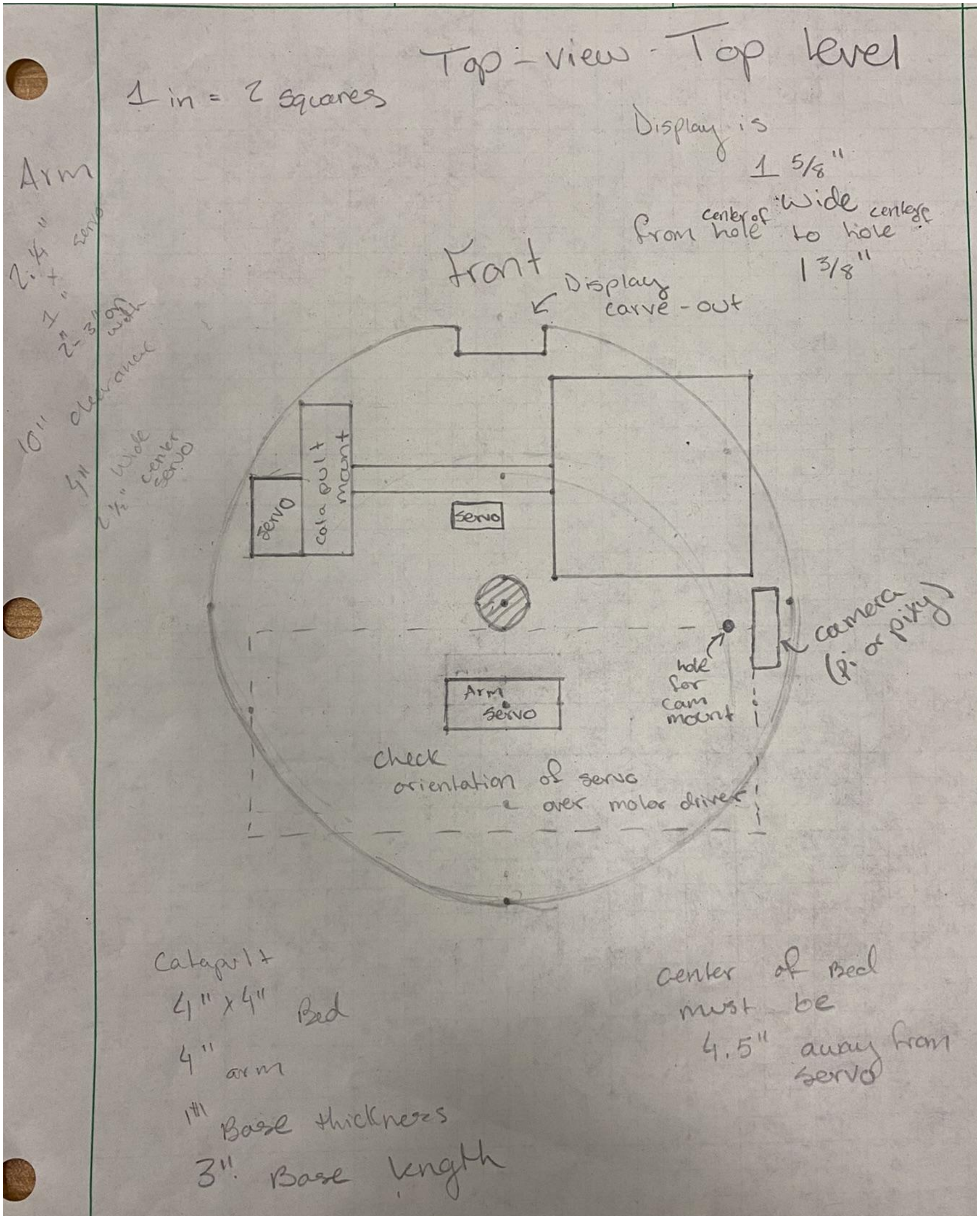


Figure 18. - Detailed Top View of Top Level

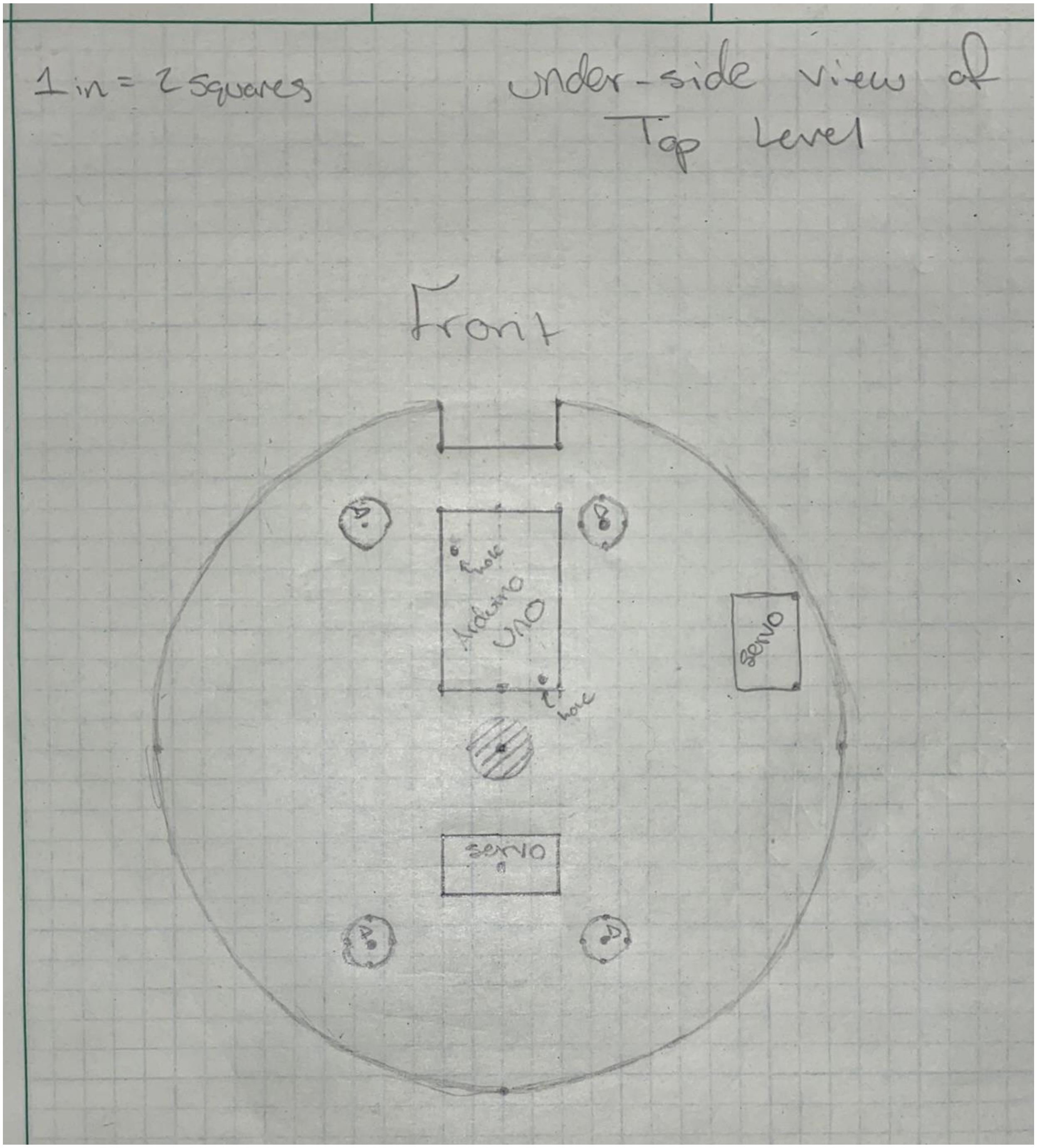
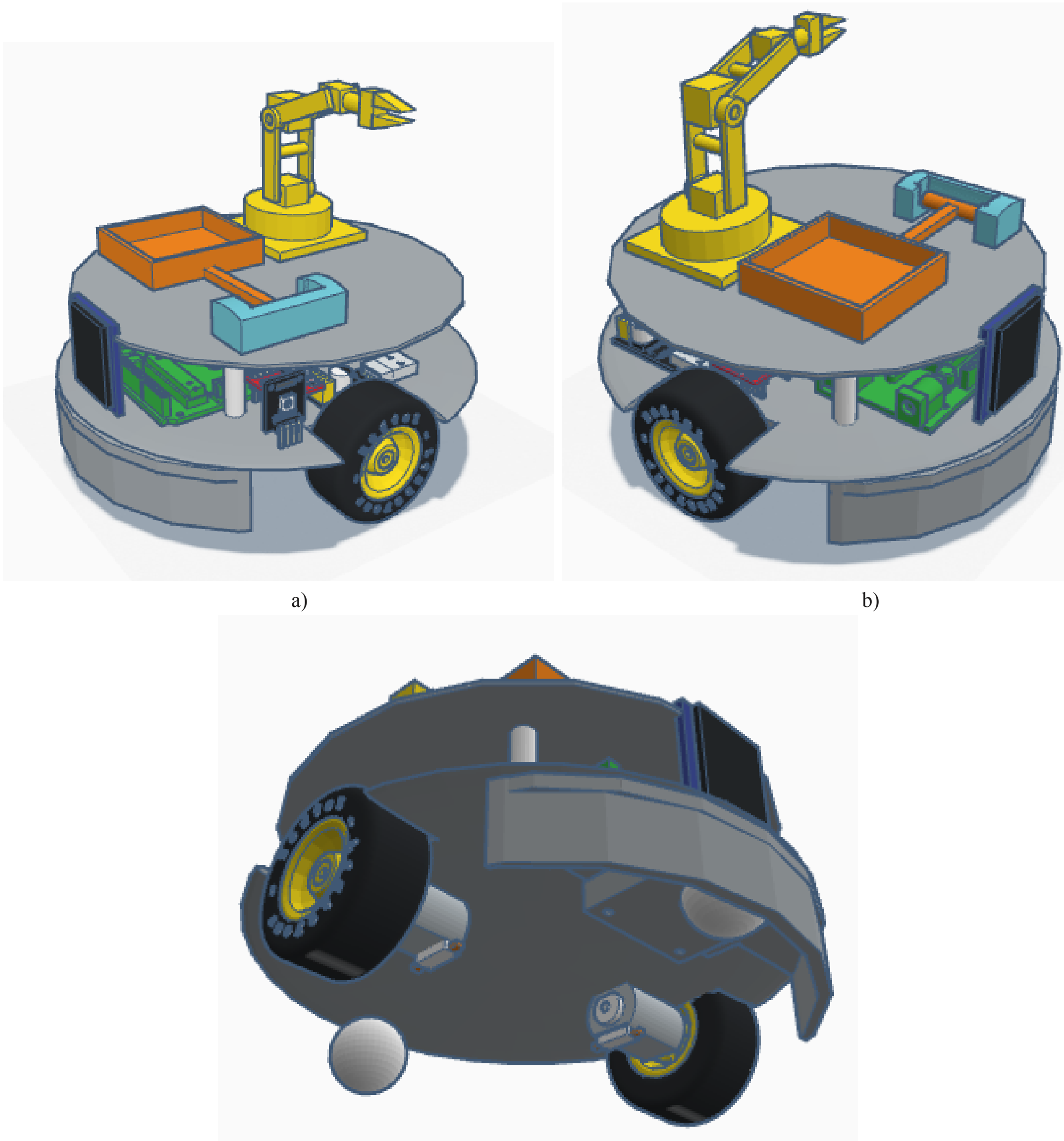


Figure 19. - Detailed BottomView of Top Level



a) b)

c)

Figure 20. - Cad Diagrams of the Final Design
a) Top Right View b) Top Left View c) Bottom View

9.6 Calculations

Current Position for the PID controller

$$Current\ Position = (EncoderValue \times NumberOfWheels \times \pi) \div (QuadratureDecoding \times CountPerRevolution \times GearRatioOfMotor)$$

Current Velocity for the PID controller

$$Current\ Velocity = (CurrentPosition - PreviousPosition) \div Time$$

Desired Velocity for the PID controller

$$DesiredVelocity = DesiredRevolutionsPerSecond/14$$

Desired Position for the PID Controller

$$Desired\ Position = PreviouslyDesiredPosition + DesiredVelocity \times Time$$

Voltage Calculated in the PID Controller

$$Voltage = K_p \times (DesiredPosition - CurrentPosition) + K_i \times ((DesiredPosition - CurrentPosition) \times T) + K_d \times (DesiredVelocity - CurrentVelocity)$$

Duty Calculated in the PID Controller

$$Duty = (Voltage \div BatteryVoltage) \times 255$$

Angular Velocity in the Line Tracking Algorithm

$$Angular\ Velocity = (2 \times (2 \times \pi \times CurrentVelocity \times WheelRadius) \times YComponentOfTheLookAheadValue) \div (LookAheadDistance)^2\ )$$

9.7 Risk Assessment

FAMU-FSU College of Engineering
Project Hazard Assessment Policy and Procedures

INTRODUCTION

University laboratories are not without safety hazards. Those circumstances or conditions that might go wrong must be predicted and reasonable control methods must be determined to prevent incident and injury. The FAMU-FSU College of Engineering is committed to achieving and maintaining safety in all levels of work activities.

PROJECT HAZARD ASSESSMENT POLICY

Prior to starting an experiment, laboratory workers must conduct a project hazard assessment (PHA) to identify health, environmental and property hazards and the proper control methods to eliminate, reduce or control those hazards. PI/instructor must review, approve, and sign the written PHA and provide the identified hazard control measures. PI/instructor continually monitor projects to ensure proper controls and safety measures are available, implemented, and followed. PI/instructor are required to reevaluate a project anytime there is a change in scope or scale of a project and at least annually after the initial review.

PROJECT HAZARD ASSESSMENT PROCEDURES

It is FAMU-FSU College of Engineering policy to implement followings:

1. Laboratory workers (i.e. graduate students, undergraduate students, postdoctoral, volunteers, etc.) performing a research in FAMU-FSU College of Engineering are required to conduct PHA prior to commencement of an experiment or any project change in order to identify existing or potential hazards and to determine proper measures to control those hazards.
2. PI/instructor must review, approve and sign the written PHA.
3. PI/instructor must ensure all the control methods identified in PHA are available and implemented in the laboratory.
4. In the event laboratory personnel are not following the safety precautions, PI/instructor must take firm actions (e.g. stop the work, set a meeting to discuss potential hazards and consequences, ask personnel to review the safety rules, etc.) to clarify the safety expectations.
5. PI/instructor must document all the incidents/accidents happened in the laboratory along with the PHA document to ensure that PHA is reviewed/modified to prevent reoccurrence. In the event of PHA modification a revision number should be given to the PHA, so project members know the latest PHA revision they should follow.
6. PI/instructor must ensure that those findings in PHA are communicated with other students working in the same laboratory (affected users).
7. PI/instructor must ensure that approved methods and precautions are being followed by :
    a. Performing periodic laboratory visits to prevent the development of unsafe practice.
    b. Quick reviewing of the safety rules and precautions in the laboratory members meetings.
    c. Assigning a safety representative to assist in implementing the expectations.
    d. Etc.
8. A copy of this PHA must be kept in a binder inside the laboratory or PI/instructor's office (if experiment steps are confidential).

Project Hazard Assessment Worksheet				
PI/instructor: Oscar Chuy	Phone #: (850) 410-6468	Dept.:ECE	Start Date: 3/29/2022	Revision number: 2
Project: SoutheastCon Hardware Competition			Location(s): Tallahassee, FL; Mobile, AL	
Team member(s): Kelvin Hamilton, Melissa Emery, Allison Rosenbaum, Raymond Martinez, Destiny Law			Phone #: (727) 686-0396	Email: kdh18@my.fsu.edu

Experiment Steps	Location	Person assigned	Identify hazards or potential failure points	Control method	PPE	List proper methods of hazardous waste disposal, if any.	Residual Risk	Specific rules based on the residual risk
Wheel testing, collector testing, catapult testing	COE, Florida. Southeast Competition, Mobile, Alabama	Raymond Martinez	Electrocution	Make sure Power is disconnected before making changes	Rubber accessories (boots, etc.)	Recycle	HAZARD: 3 CONSEQ: Significant Residual: Med High	Two workers at a time, approval from faculty
Microprocessor and microcontroller handling: Arduino, motor driver, etc.	COE, Florida. Southeast Competition, Mobile, Alabama	Raymond Martinez	Electrostatic discharge damage	Discharge static by grounding self before handling	Anti Static band/mat	Recycle	HAZARD: 1 CONSEQ: Minor Residual: Low	Safety precautions are in place, proceed with project manager authorization
Collecting and catapult mechanism testing	COE, Florida. Southeast Competition, Mobile, Alabama	Allison Rosenbaum	Projectile Hazard	Make sure no personnel is in line of fire of projectiles	Goggles	Recycle/Trash	HAZARD: 2 CONSEQ: Significant Residual: Low Med	Two workers at a time, approval from project manager
All testing involving self-contained robot system	COE, Florida. Southeast Competition, Mobile, Alabama	Kelvin Hamilton	Battery Explosion	Calculate power and verify cable connections before powering on	Latex gloves	Hazardous waste center (Leon County) (https://bit.ly/3CaieVM)	HAZARD: 4 CONSEQ: Significant Residual: Med High	Two workers at a time, approval from faculty
Game board assembly/modification and robot construction	Computer Communication Lab	Kelvin Hamilton	Construction and assembly tools	Sand down wood components, Keeping body parts clear of exposed blades	Goggles, gloves, functional tools	Recycle/Trash	HAZARD: 2 CONSEQ: Severe Residual: Medium	Two workers at a time, approval from project manager
Wheel testing, catapult testing, collector testing	COE, Florida. Southeast Competition, Mobile, Alabama	Melissa Emery	Body Part / accessories damaged by components	Ensure all personnel takes off loose accessories that can get caught in components	Goggles, hair tie	N/A	HAZARD: 1 CONSEQ: Significant Residual: Low Med	Two workers at a time, approval from project manager

Residual risk: Residual Risk Assessment Matrix are used to determine project's risk level. The hazard assessment matrix (table 1) and the residual risk assessment matrix (table2) are used to identify the residual risk category.

The instructions to use hazard assessment matrix (table 1) are listed below:

1. Define the workers familiarity level to perform the task and the complexity of the task.
2. Find the value associated with familiarity/complexity (1 – 5) and enter value next to: HAZARD on the PHA worksheet.

Table 1. Hazard assessment matrix.

		Complexity		
		Simple	Moderate	Difficult
Familiarity Level	Very Familiar	1	2	3
	Somewhat Familiar	2	3	4
	Unfamiliar	3	4	5

The instructions to use residual risk assessment matrix (table 2) are listed below:

1. Identify the row associated with the familiarity/complexity value (1 – 5).
2. Identify the consequences and enter value next to: CONSEQ on the PHA worksheet. Consequences are determined by defining what would happen in a worst case scenario if controls fail.
   a. Negligible: minor injury resulting in basic first aid treatment that can be provided on site.
   b. Minor: minor injury resulting in advanced first aid treatment administered by a physician.
   c. Moderate: injuries that require treatment above first aid but do not require hospitalization.
   d. Significant: severe injuries requiring hospitalization.
   e. Severe: death or permanent disability.
3. Find the residual risk value associated with assessed hazard/consequences: Low –Low Med – Med– Med High – High.
4. Enter value next to: RESIDUAL on the PHA worksheet.

Table 2. Residual risk assessment matrix.

Assessed Hazard Level	**Consequences**				
	Negligible	Minor	Moderate	Significant	Severe
5	Low Med	Medium	Med High	High	High
4	Low	Low Med	Medium	Med High	High
3	Low	Low Med	Medium	Med High	Med High
2	Low	Low Med	Low Med	Medium	Medium
1	Low	Low	Low Med	Low Med	Medium

Principal investigator(s) PHA certification: I certify that I have reviewed and approved the PHA worksheet and will ensure the control measures are available and implemented in the laboratory.

Name	Signature	Date	Name	Signature	Date
Oscar Chuy	DocuSigned by: Oscar Chuy F2E19426A17D40B...	4/7/2022 | 5:40 AM EDT	Bruce Harvey	DocuSigned by: Bruce Harvey 03F4919EB09848F...	4/7/2022 | 6:40 A

Team members' certification: I certify that I have reviewed the PHA worksheet, am aware of the hazards, and will ensure the control measures are followed.

Name	Signature	Date	Name	Signature	Date
Raymond Martinez	DocuSigned by: Raymond Martinez	4/7/2022 | 12:18 AM EDT	Destiny Law	DocuSigned by: Destiny Law	4/7/2022 | 12:23
Melissa Emery	Melissa Emery 8C0FFE3E93784 60...	4/7/2022 | 12:20 AM EDT	Allison Rosenbaum	DocuSigned by: AD971BBEEE114CA...	4/7/2022 | 12:11
Kelvin Hamilton	DocuSigned by: Kelvin Hamilton 2A0DE1792E77442...	4/7/2022 | 12:10 AM EDT			

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DEFINITIONS:

Hazard: Any situation, object, or behavior that exists, or that can potentially cause ill health, injury, loss or property damage e.g. electricity, chemicals, biohazard materials, sharp objects, noise, wet floor, etc. OSHA defines hazards as *"any source of potential damage, harm or adverse health effects on something or someone"*. A list of hazard types and examples are provided in appendix A.

Hazard control: Hazard control refers to workplace measures to eliminate/minimize adverse health effects, injury, loss, and property damage. Hazard control practices are often categorized into following three groups (priority as listed):

1. **Engineering control:** physical modifications to a process, equipment, or installation of a barrier into a system to minimize worker exposure to a hazard. Examples are ventilation (fume hood, biological safety cabinet), containment (glove box, sealed containers, barriers), substitution/elimination (consider less hazardous alternative materials), process controls (safety valves, gauges, temperature sensor, regulators, alarms, monitors, electrical grounding and bonding), etc.
2. **Administrative control:** changes in work procedures to reduce exposure and mitigate hazards. Examples are reducing scale of process (micro-scale experiments), reducing time of personal exposure to process, providing training on proper techniques, writing safety policies, supervision, requesting experts to perform the task, etc.
3. **Personal protective equipment (PPE):** equipment worn to minimize exposure to hazards. Examples are gloves, safety glasses, goggles, steel toe shoes, earplugs or muffs, hard hats, respirators, vests, full body suits, laboratory coats, etc.

Team member(s): Everyone who works on the project (i.e. grads, undergrads, postdocs, etc.). The primary contact must be listed first and provide phone number and email for contact.

Safety representative: Each laboratory is encouraged to have a safety representative, preferably a graduate student, in order to facilitate the implementation of the safety expectations in the laboratory. Duties include (but are not limited to):

- Act as a point of contact between the laboratory members and the college safety committee members.
- Ensure laboratory members are following the safety rules.
- Conduct periodic safety inspection of the laboratory.
- Schedule laboratory clean up dates with the laboratory members.
- Request for hazardous waste pick up.

Specific rules for each category of the residual risk:

Low:
- Safety controls are planned by both the worker and supervisor.
- Proceed with supervisor authorization.

Low Med:
- Safety controls are planned by both the worker and supervisor.
- A second worker knowledgeable of the task and hazards is in the vicinity (buddy system).
- Proceed with supervisor authorization.

Med:
- After approval by the PI, the Safety Committee and/or EHS must review and approve the completed PHA.
- A written safety plan is required and must be approved by the PI before proceeding. A copy must be sent to the Safety Committee.
- A second worker must be in place before work can proceed (buddy system).
- Limit the number of authorized workers in the hazard area.

Med High:
- After approval by the PI, the Safety Committee and/or EHS must review and approve the completed PHA.
- A written safety plan is required and must be approved by the PI and the Safety Committee before proceeding.
- Two qualified workers must be in place before work can proceed.
- Limit the number of authorized workers in the hazard area.

High:

The activity will not be performed. The activity must be redesigned to fall in a lower hazard category.

Appendix A: Hazard types and examples

Types of Hazard	Example
Physical hazards	Wet floors, loose electrical cables objects protruding in walkways or doorways
Ergonomic hazards	Lifting heavy objects Stretching the body Twisting the body Poor desk seating
Psychological hazards	Heights, loud sounds, tunnels, bright lights
Environmental hazards	Room temperature, ventilation contaminated air, photocopiers, some office plants acids
Hazardous substances	Alkalis solvents
Biological hazards	Hepatitis B, new strain influenza
Radiation hazards	Electric welding flashes Sunburn
Chemical hazards	Effects on central nervous system, lungs, digestive system, circulatory system, skin, reproductive system. Short term (acute) effects such as burns, rashes, irritation, feeling unwell, coma and death. Long term (chronic) effects such as mutagenic (affects cell structure), carcinogenic (cancer), teratogenic (reproductive effect), dermatitis of the skin, and occupational asthma and lung damage.
Noise	High levels of industrial noise will cause irritation in the short term, and industrial deafness in the long term.

Temperature	Personal comfort is best between temperatures of 16°C and 30°C, better between 21°C and 26°C. Working outside these temperature ranges: may lead to becoming chilled, even hypothermia (deep body cooling) in the colder temperatures, and may lead to dehydration, cramps, heat exhaustion, and hyperthermia (heat stroke) in the warmer temperatures.
Being struck by	This hazard could be a projectile, moving object or material. The health effect could be lacerations, bruising, breaks, eye injuries, and possibly death.
Crushed by	A typical example of this hazard is tractor rollover. Death is usually the result
Entangled by	Becoming entangled in machinery. Effects could be crushing, lacerations, bruising, breaks amputation and death.
High energy sources	Explosions, high pressure gases, liquids and dusts, fires, electricity and sources such as lasers can all have serious effects on the body, even death.
Vibration	Vibration can affect the human body in the hand arm with `white-finger' or Raynaud's Syndrome, and the whole body with motion sickness, giddiness, damage to bones and audits, blood pressure and nervous system problems.
Slips, trips and falls	A very common workplace hazard from tripping on floors, falling off structures or down stairs, and slipping on spills.
Radiation	Radiation can have serious health effects. Skin cancer, other cancers, sterility, birth deformities, blood changes, skin burns and eye damage are examples.
Physical	Excessive effort, poor posture and repetition can all lead to muscular pain, tendon damage and deterioration to bones and related structures
Psychological	Stress, anxiety, tiredness, poor concentration, headaches, back pain and heart disease can be the health effects
Biological	More common in the health, food and agricultural industries. Effects such as infectious disease, rashes and allergic response.

Project Hazard Assessment - Project Narrative

Name of Project: SoutheastCon Hardware Competition		Date of submission: 4/6/2022
Team member	**Phone number**	**e-mail**
Kelvin Hamilton	727-686-0396	kdh18@my.fsu.edu
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Raymond Martinez	850-247-3851	rjm18b@my.fsu.edu
Destiny Law	407-446-1582	destiny1.law@famu.edu
Faculty mentor	**Phone number**	**e-mail**
Bruce Harvey	(850) 410-6451	bharvey@eng.famu.fsu.edu
Oscar Chuy	(850) 410-6468	chuy@eng.famu.fsu.edu

Rewrite the project steps to include all safety measures taken for each step or combination of steps. Be specific (don't just state "be careful").

We'll ensure the power is disconnected during component testing before changing any connections. The necessary personnel will have rubber accessories (soles, etc.) to ensure their safety and combat electrocution. When handling the microprocessor and microcontroller, an anti-static band/mat will be used to reduce the chance of electrostatic discharge damage. Personnel will use goggles to protect themselves from any projectile hazards due to the catapult mechanism and to shield eyes from loose debris during game board assembly. If necessary, latex gloves will be used and Leon County's waste center will be utilized to clean battery explosions. Hair ties will be utilized to keep hair from getting caught in any spinning mechanisms such as the wheels. During high voltage electronic, projectile, battery, and spinning mechanism handling, it is required for two members to work together. Two members also must be present during game board assembly/modification. Batteries will be the only potentially hazardous waste present, and we will follow the waste center's instructions for proper handling. For other components and game board materials, standard recycling and trash can be utilized.

Thinking about the accidents that have occurred or that you have identified as a risk, describe emergency response procedures to use.

- Assess the level of damage
- Apply First Aid if needed
- Contact necessary officials and/or emergency contacts
- Proceed with cleaning up any debris if necessary
- Take note of faults in safety procedure and adjust procedure accordingly for future experiments

List emergency response contact information:

- Call 911 for severe injuries, fires or other emergency situations
- Call department representative to report a facility concern

Name	Phone number	Faculty or other COE emergency contact	Phone number
Alec Klinger (Melissa)	(954)328-3986	Jerris Hooker	(850)410-6463
Christopher Castro(Raymond)	(954)662-9416	Bruce Harvey	(850)410-6451
Amanda De La Cruz (Allison)	(201)753-2224	Oscar Chuy	(850)410-6468
Olivia Fields (Kelvin)	(352)238-5833	Linda DeBrunner	(850)410-6462
Lisa Wright (Destiny)	(407)541-9593	Babak Noroozi	(901)515-7371

Safety review signatures

Team member	Date	Faculty mentor	Date
Kelvin Hamilton	4/7/2022 | 12:10 AM EDT	Oscar Chuy	4/7/2022 | 5:40 AM
Melissa Emery	4/7/2022 | 12:20 AM EDT		
[illegible]	4/7/2022 | 12:11 AM EDT	Bruce Harvey	4/7/2022 | 6:40 AM
Raymond Martinez	4/7/2022 | 12:18 AM EDT		
Destiny Law	4/7/2022 | 12:23 AM EDT		

Report all accidents and near misses to the faculty mentor.

Revised 06-2019