Final Project

MCHE 201: Introduction to Mechanical Design

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Abstract

This report analyzes the final design and results, as well as the construction process and design tools, used to develop a robot for the final Star Wars robotics competition. The contest entails a four team head-to-head match to determine the device that can complete the most tasks and receive maximum points in a 30 second round. Any device that uses the mechatronic kit as an energy source is capable of competing, as long as the device meets all other regulations of admission. Design requirements are created based on objectives of the competition, as well as the contest enforced rules. Some of the most important requirements include: less than 12 x 24 x 18 inches' dimensions, high velocity motors, and a run time of less than 30 seconds. A House of Quality, as well as a Specification Sheet, were used in order to better evaluate these requirements. These tool offers a strong understanding of the challenges by relating the design requirements to engineering characteristics. ~~The engineering characteristics are assigned specific numerical values that are desired by the design team and competition in the Specification Sheet~~. Some of the most important engineering characteristics are the dimensions of the robot, the lateral reach of the arms, and the time it takes to complete each task. Based off of these results, several different designs features were proposed for the final device, as well as the alternatives. The Concept Evaluation Matrix presents the three design ideas and evaluates the designs according to how well it exceeds the engineering challenges that are listed in the House of Quality. The final design chosen was the Scorpion. The key functionality the Scorpion possesses is its lateral reach. With the arms at maximum extent, the lateral span is approximately 43 inches. The advantage of a wide lateral span is to possibly attempt to collect all four droids on the outer edges of the zone. Not only does the Scorpion have a wide lateral reach, but also a one-half gear ratio attached to the large DC motor that is connected to the drive shaft. The drive system allows the Scorpion to have first contact with droids; therefore this is a possible automatic 20 points. The results at the final robotics competition are the Scorpion ranked 13th out of 25 possible rankings. The Scorpion completed four rounds before being eliminated. A more detailed explanation of the Scorpion is presented in the various sections of the paper.

Good

I. Introduction

The Star Wars robotics competition is an autonomous robotics tournament that pits four robots against each other in a competition to see which device can gain the most points by completing a number of different tasks. The playing field, as shown in Figure 1 [1], for the competition consists of a platform with various objects scattered in each contestants' zone that are assigned particular point values. The point values are used to create a ranking system for the competitors. Once the device is placed on one of the four starting zones, the seven-minute time limit begins. Four of the seven minutes are dedicated to setting up the device, while the remaining time is for the 30 seconds of completing the task and clean up. The list of available tasks as well as the points awarded are as followed: 5 points are awarded for each torpedo that lands in the Death Star, or 10 points for each torpedo that is placed into the exhaust port, 5 points for each force unit that is collected and placed into the training zone. Additionally, a team can get 5 points for collecting the light saber into the training zone or a possible 10 points if the lightsaber is standing upright. A team can be deducted 10 points for each TIE fighter that is left in a team's zone at the end of the time limit. All of different task create several engineering challenges that the robot must overcome. These challenges include: dimension restrictions, enhance motor speeds using gear ratios, lateral reach extensions, and most importantly the time it takes to complete each task to stay in the 30 second time interval. The final design will be evaluated throughout the following sections. In Section II, a detailed analysis of the final design will be presented. Section III will give a brief outline of the crucial aspect of the problem understanding tools. The process of establishing the Evaluation Matrix for the three design ideas to reveal the final choice is identified in Section IV. Section V contains an evaluation of the robot's overall performance in the competition, as well as an overview of the assumptions made before competing in the competition. A synopsis of the report will be concluding in section VI.

why are these challenges?

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II. Final Design

The final design is a mobile robot with a rear wheel drive that allows it to move forward and backwards. The design features two sweeping arms that fit precisely on the both sides of the device and rotate outward in order to collect droids, as well as force units. A torpedo arm is mounted on the back of the device in order to deposit the torpedoes into the death star. Lastly, two sponge barriers are located on each side of the device and drop down in order to push the sponges out of the team zone as the robot goes in reverse to escape the death star.

A detailed diagram of the final device in its initial position can be seen in Figure 2. The body of the device is landscape oriented and measures 11.5 x 22 x 16 inches. Instead of metal, the device is composed nearly entirely out of wood. The wood allows the device to be reasonably strong, while still being fairly lightweight and low cost. Most of the structure of the device comes from two 2 x 4 inch pieces of wood that are approximately 9.5 inches long and lie parallel to one another. The drive shaft runs through one end of the 2 x 4 pieces, and at the other end is a pair of 4x 22-inch piece of plywood roughly 4 inches apart that lie flush on top of the 2x4's.

The drive system, seen in Figure 3, is a rear drive setup that allows the device to travel forward and backwards. The system uses a large DC motor to turn a drive shaft connected to two wheels. The stock DC motor is connected to the driveshaft with a 0.5 ratio gear system, allowing the device to travel twice the maximum speed of the motor. The driveshaft itself is connected to the body of the device with ball bearing rings on each side in order to negate frictional effects on the shaft by the weight of the device, as shown in Figure 3. At the end of each side of the driveshaft are six-inch rubber wheels to increase the traction.

usually written as a proportion

The sweeping arms are located on either side of the device, as shown in Figure 4, and are sized in order to conveniently fit in open position at the initial state of the device. The arms are L shaped and measure 4.75 inches on the short section and 11.5 inches on the long section. A cardboard barrier is attached to the arms to prevent any force units from sliding underneath them. The arms lie underneath a piece of plywood and are connected to pins that run through two horizontally parallel layers of plywood. Wooden cylinders and springs are also connected to the pins and are inserted in between the plywood, as shown in Figure 5. One end of string is attached to and wrapped around the wooden cylinders, while the other end is attached to a linear actuator. The linear actuator extends pulling the string and causing the pins and arms to rotate. When the linear actuator retracts the string is given slack. The springs cause the arms to rotate back in the opposite direction to its original state. This setup allows the arms to rotate both clockwise and counterclockwise 270 degrees.

The torpedo arm is attached at a 45-degree angle on the back of the device in order to fit within the devices starting dimensions. The arm sits in a folded state initially, and is extended by a small DC motor in two parts. The primary section of the arm consists of a ball bearing track that can be extended twice its length, nearly 20 inches. Once the primary section is fully extended, the secondary section rotates 45 counterclockwise in order to give more reach. The secondary section adds an additional 3 inches. Completely extended, the arms measures approximately 23 inches long, which allows the device to drop torpedoes at a lateral distance of 22 inches. The dropping mechanism is located on the end of the secondary section. A servo powered trapdoor is used to deploy the torpedoes once the arm reaches max length. The extension of the arms is powered by reeling in a string that is laced through both sections of the Torpedo arm. The string is reeled by a 1.5-inch wheel that is connected to the small DC motors through a two-thirds gear ratio system. The setup, illustrated in Figure 6, allows the motor to reel in the string at a faster rate, therefore extending the Torpedo arm quicker.

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Finally, the sponge barriers are located underneath the plywood wings on each side of the device. The barriers are made out of cardboard that are initially in a folded position held in place by two servo motors. The barriers are deployed only after the sweeping arms are released and the device has driven towards the death star. The barriers drop down to 1 inch above the ground and allow the device to push the sponges out of the team zone as the device returns to the start zone to escape the Death Star explosion.

III. Problem Understanding

The organization of this section needs some work.

In order to better understand the concepts of the challenges in the contest, the following problem solving tools were used: House of Quality, Specification Sheet, and Function Tree. The House of Quality, shown in Table 1, can help identify customer requirements of a device competing in the contest, as well as, connect the requirements to engineering characteristics. The Specification sheet, in Table 2, specifies numerical values for these engineering characteristics. The Function Tree, in Figure 7, list the objectives to accomplish by breaking down the most complex task to the least.

Don't reference the tools until you are ready to discuss them in detail

One of the most important challenges in the competition is complying with the 12 x 24 x 18-inch size restriction. These dimensional limits are among the most important customer requirements, because failing to conform results in disqualification. However, it is beneficial to maximize these dimensions as much as possible, while still meeting the size requirements. For this reason, a specification for the dimensions were set at 1 inch or more under the size cap.

Ref HoQ here

Another challenge that is addressed is the time constraints of the contest. A customer requirement is set to restrict the total run time to 30 seconds, in order to avoid disqualification. This requirement is vital to the overall performance of the design, since completing objectives quicker than others directly correlates to a higher point count. The breakdown of the time restraint is broken down in the Specification Sheet, as seen in Table 2, and the Function Tree, shown in Figure 7. By maximizing the device's drive speed, this causes the robot to move around the platform quicker. The correlation matrix, as shown at the top of the House of Quality in Table 1, indicates that the drive speed can be increased by also increasing the RPM of the drive shaft, the radius of the wheels, as well as the traction of the wheels to minimize slipping. The device can also complete objectives quicker by minimizing the motors' gear ratios, which will result in

constraints don't belong in Func Tree

maximizing the motors' speed. The devices gear ratio specification is currently between ½ and ¾ giving between a 100% and a 75% increase to the rotational speed of the motors.

Since different objectives offer different amounts of points. It is important to prioritize the objectives the device will performs and the order in which to complete each one in. The main objectives that are focused on are: delivering torpedoes, depositing force units, removing TIE fighters, and escaping the explosion. According to the House of Quality, Table 1, the characteristics that dictate these four requirements are the device's dimensions, as well as it lateral and longitudinal reach. In this case, the width and lateral reach of the device were determined to be the more important of the two, lending to the decision for the device to be landscape oriented, as noted in the Specification Sheet in Table 2. The Function Tree, Figure 7, provides the complexity of each task to support the rankings of importance that were assigned. All of the objects are broken down for any design to comply with.

Due to the tournament style competition, it is important for a device to be able to execute the run reliably multiple times without failing. The design must be resilient to outside forces, as well as creep stress. The structural stability of the device mostly depends on the stress rating of the material used to design it. Any creep stress that the device experiences will result in its own weight, therefore minimize weight would be just as harmful as it would be helpful. The correlation matrix, displayed in the top of Table 1, shows a negative correlation between stress rating and weight. A balance of the two must be made. The decision for wood to be the standard building material was specified in addition to using oak wood in the sections that required the most strength.

Lastly, improving the reliability of the code will reduce the error in the runs that will minimize malfunctioning. The less malfunctions that occur the more reliable the run will be. This will result in maximum points to be earned each time the robot competes. The code is majorly based off of timing. If the timing is not set precisely to the desired location the ability to earn maximum points will be inconsistent.

IV. Concept Evaluation

A third-level Evaluation Matrix is used to evaluate each design based on how well it will complete each task, as well as how simple it will be to construct. These concepts are listed in the customer requirements on the left side in Table 1. In the third-level Evaluation Matrix Table 3, the designs are shown along with the assigned point values according to the scale. The first design, which is the final design, has the highest absolute total of 1230. The absolute total is acquired by multiplying the assigned importance by the value given based on the scale. Each design also has a relative total, which is the absolute total divided by the max points. The final design has a relative total of 0.79. Based on these numbers and other factors, the final design was chosen since the table indicated that not only would it be fairly easily constructed, but also comply with the regulations of the contest.

You need to introduce all concepts first without specs the concepts, the eval. is impossible to follow.

The first alternative design, as shown in Figure 8, is a simple car-like robot. An advantage of this design, similar to the stationary robot, is the simplicity of the code. With having a simple design, there is less room for error and malfunctioning of parts. However, a disadvantage of the simple-car design is that it cannot complete all the task needed to receive maximum points. The simple car design does not consistently deposit the torpedoes into the Death Star, therefore it received a seven out of ten in this category in Table 3. The lightsaber tends to set the robot off its designated path considering its lightweight structure, hence the assigned value of five out of ten in this area on Table 3. Also, as a result of the designs simplicity, it is hard to add complex mechanical detail to the structure. The design provides no room for additional add-ons, therefore this causes objectives to be eliminated from being achieved.

Save pro/con for eval matrix discussion

The second alternative design, as shown in Figure 9, is a stationary robot. A downfall of having a stationary robot is the mobile robots have an advantage of obtaining the droids first. Also, the stationary robot's lateral reach would have to be greater than a mobile robot's reach considering it can not move forward. The issue of possibly exceeding the dimensional restriction occurs. Another disadvantage that exist with using this design is attempting to deposit the objects into the Jedi training zone. This category received a four out of 10 because the robot is not allowed to move further back than where it is originally placed on the board. Therefore, this could cause the object to not completely be deposited into the zone. One of the advantages of constructing a stationary device is that there are more motors to use for different task rather than using a motor to operate the drive shaft. This also allows the code to focus on achieving the objectives without concerning about the timing of the code for the robot's positioning. In Figure 7, the stationary received an 8 out of 10 for having an easy code to manipulate.

save pro/con for eval matrix discussion

Intro all concepts, then evaluate them.

Lastly, with all of the previously mentioned requirements and characteristics of both alternative designs in mind, the decision of the most realistically ideal design is chosen based on the ranks provided by the Third-level Evaluation Matrix, as seen in Table 3. The rankings of the Evaluation Matrix provided the additional information needed to conclude that the Scorpion was the most ideal design. The final design, the Scorpion, has the potential to have up to a 40 to 44-inch lateral reach. This ensures that the four droids are possible point candidates causing the assigned point values to range from an eight to a nine in accomplishing the various task involving lateral reach. The Scorpions is designed landscape; therefore, the robot covers more ground than a portrait robot would. With more ground being covered, the objective of removing the TIE Fighters becomes easier, which provided a value of a nine out of ten in this area. The Scorpion is set high off the ground; as a result, the lightsaber does not offset the robot when it comes in contact with it. Also, since the robot is landscape and narrow, escaping the Death Star explosion becomes a simple task. The mechanical torpedo arm that is connected to the small DC motor and has a servo attached to its end provides an accurate deposit into the death star. A downfall to this design is positioning the robot in the right place at the right time to accomplish each task. The manipulation of coding provides precise location to achieve the desired task. Overall, with the Concept Evaluation Matrix, Table 3, and other problem understanding tools, the final design was chosen due to its simplistic build, complex mechanics, and its accuracy of completing task.

good

V. Design Performance Evaluation

During the the final competition, the Scorpion, shown in Figure 2, competed against various other competitors to obtain maximum points in a 30 second round. The final competition was double elimination. Overall, the goal was to make it into the final round. However, after completing four rounds the Scorpion was eliminated. The Scorpion ranked 13th out of a possible 25. Not only were the robots evaluated based on performance, but also aesthetics, ingenuity, and presentation. The scoring received are as followed: in aesthetics a 7.21, ingenuity 8.00, lastly presentation a 7.86. Resulting in an overall total of 7.69. The challenges the competition posed were different than some of the expectations that were formed. Some of the challenges of the overall competition were designing a robot that can complete all task, creating a code that will accurately position and perform the intended task, and increasing the motor speeds.

Also, another challenge that was faced was the model and positioning of wheels. The first prototype of the Scorpion had three wheels, as seen in Figure 2. Two wheels were placed on the back side parallel to the vertical plywood of the base. The third wheel was placed in the front center underneath the base. With the third wheel being placed under the center of the base it raised the front end of the device. The downfall of the raised front end was that it caused the arms to pass slightly over the tops of the droids. However, an advantage was that when coming in contact with the lightsaber it did not offset the desired path of the robot. For the second prototype, right before the qualifying round, the center wheel was removed then two wheels parallel to the vertical plywood base were placed, shown in Figure 10. The new wheels made the device

Talk about the design process, not your fabrication process

Avoid "tweaking" type discussion

Avoid chronological, narrative construction completely level. The droids were in the height reach of the leveled device, but the lightsaber now caused the robot to be forced out of its directed zone. Therefore, the Scorpion was reverted back to the original three-wheel design. The downfall of the four wheel leveled design is much greater than the downfall of the three-wheel design.

The last major challenge throughout the competition was the precision of the code. A second delay in an action would cause the robot to risk the loss of gaining points. The coding was

It need not be.

a trial-and-error process. The first task was to get the time perfectly opening, shown in Figure 4 and closing the arms. Opening the arms, needed to happen as quick as possible to make first contact with the droids. Next, the arms needed to closes as soon as it made contact with all four droids. Instead of closing the arms fully, the arms close halfway; while the robot ran into the bin allowing the bin to knock all of object into the arms' reach and fully close the arms. Lastly, the arms had to open once the robot arrived at the Jedi training zone. After the timing of the arms were accomplished, escaping the Death Star was the next task to perfect. If escaping the Death Star was not accurate, the risk of running the code to long, which causes disqualification, or the robot falling off of the board and being damaged would be possible results.

VI. Conclusion

Overall, the Star Wars competition provides various tasks that can be completed based on the ranking system personally assigned to each based on the amount points desired to obtain. The problem solving tools are used to prioritize each task, as well as the customer requirements and engineering characteristics. These tools allowed the Scorpion to have one of the most complex and unique design at the competition. The task that were prioritized when designing the Scorpion were saving the droid, delivering the torpedoes, escaping the Death Star explosion, lastly collecting force units. Learning to use the lightsaber was the least prioritized task because of its unpredictability to contain the lightsaber in the Jedi training zone. Along with the problem solving tools, the Concept Evaluation Matrix allows a numerical representation of the designs' ability to exceed each customer requirement for the competition. The problem solving tools and Concept Evaluation Matrix eliminated the alternative designs. The final design, ~~as seen in Figure 2~~, was chosen based on its compatibility to comply with the contest rules and a simplistic build. The Scorpion ranked 13th out of possible 25 in the final Star Wars competition. Even though these were not the desired results, overall the Scorpion was a complete success.

Don't put figure in conclusion

VII. References

[1] Vaughan, Joshua. "Star Wars: MCHE 201: Introduction to Engineering Design, Full Final Rules." (2017): http://crawlab.org/classes/MCHE201_Fa17/Projects/MCHE201_FinalProject_Fall2017.pdf

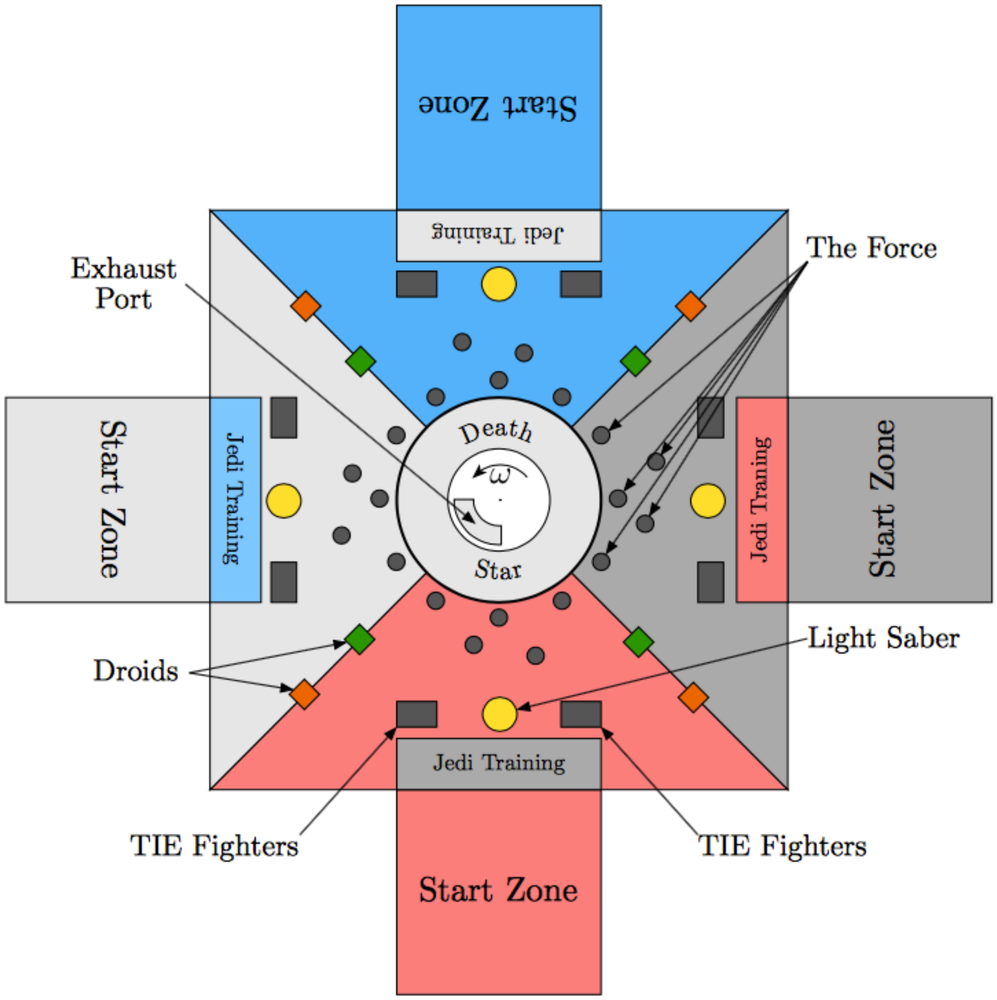


Figure 1. Robotics Track [cite]

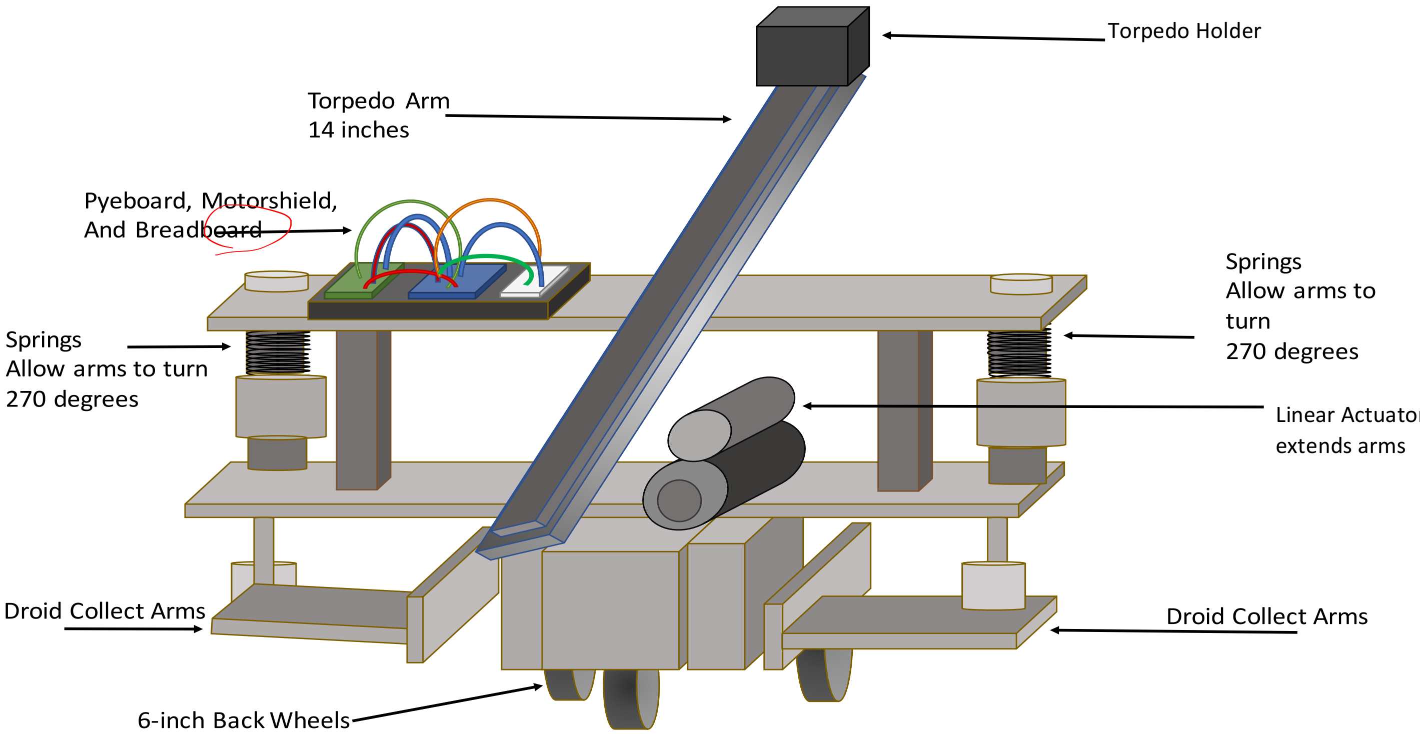


Figure 2. Final Design in initial position.

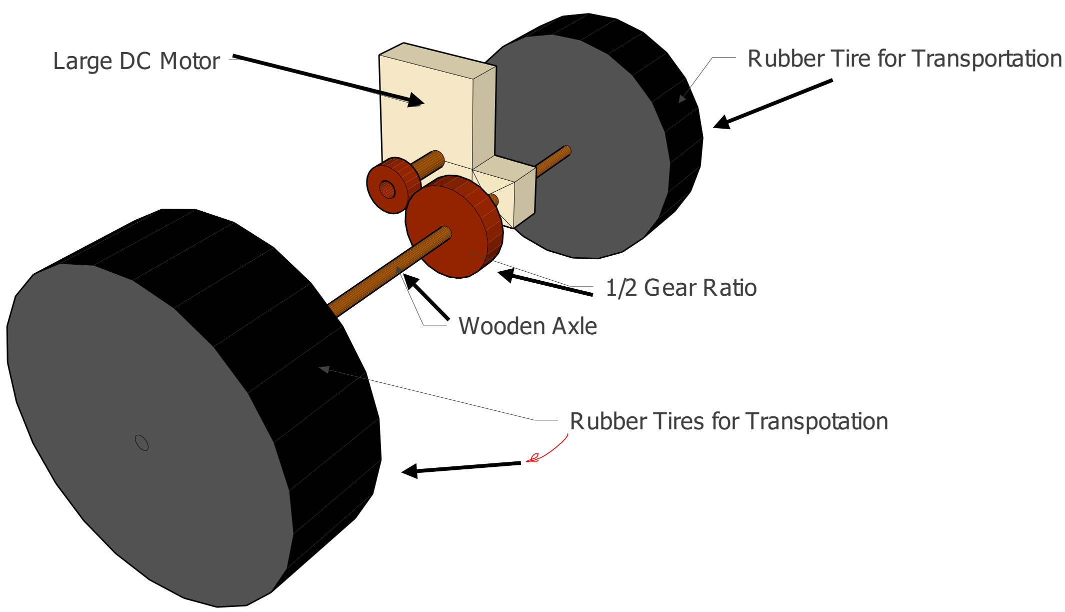


Figure 3. The driveshaft system

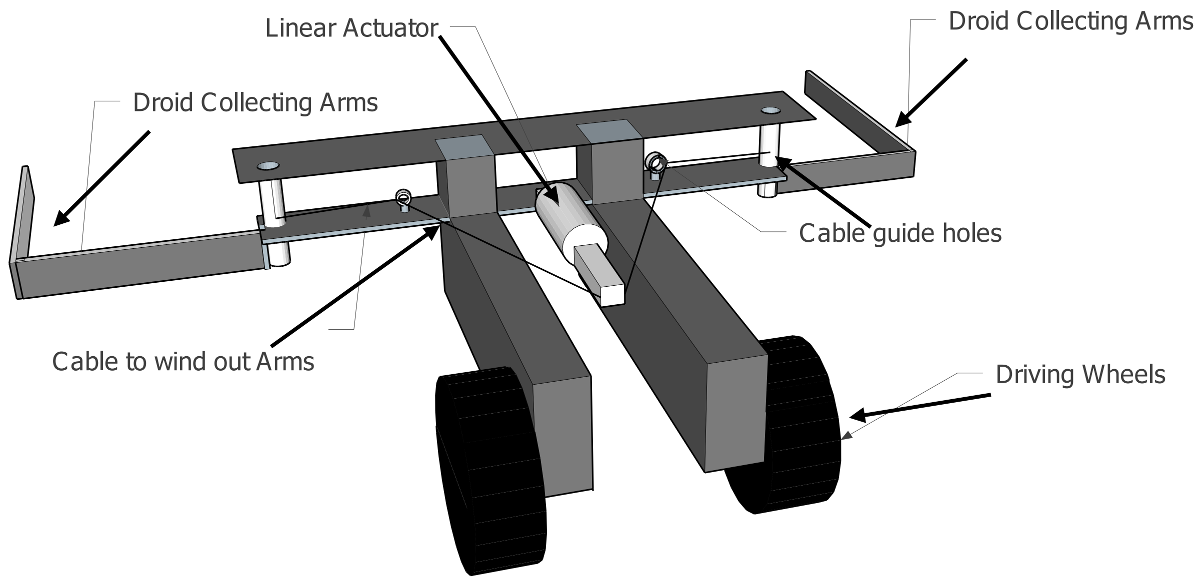


Figure 4. Final Design without the torpedo arm with arms extended open.

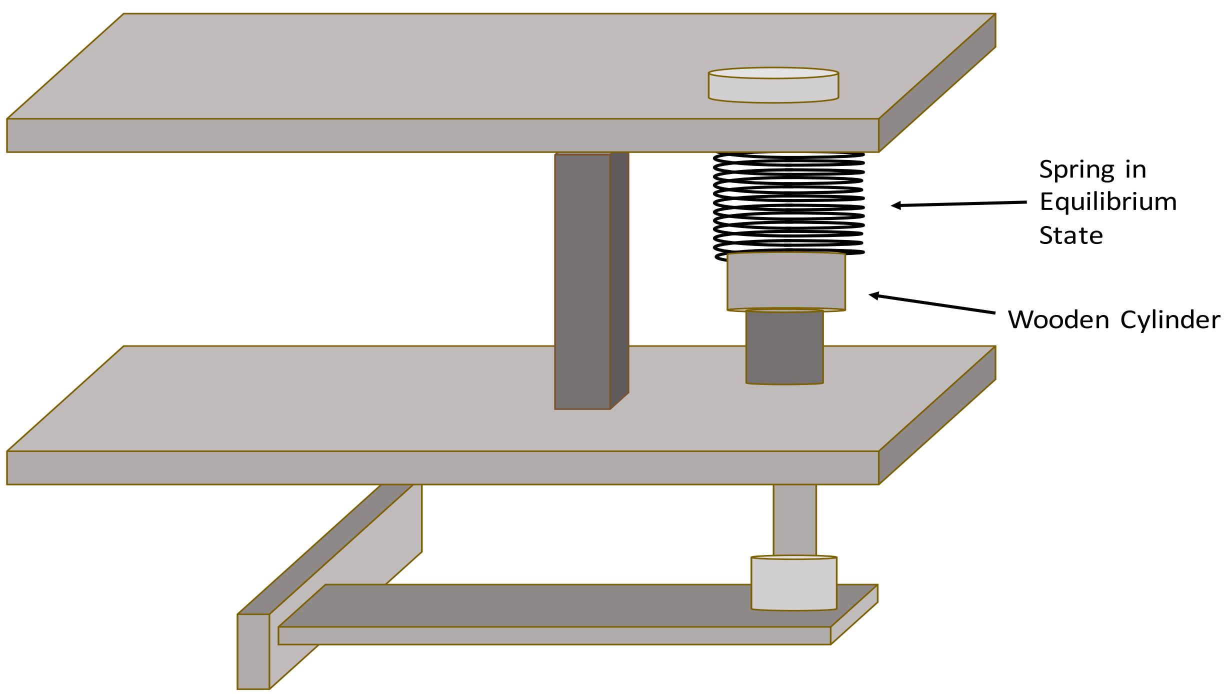


Figure 5. Spring system that allows the arms to rotate 270 degrees.

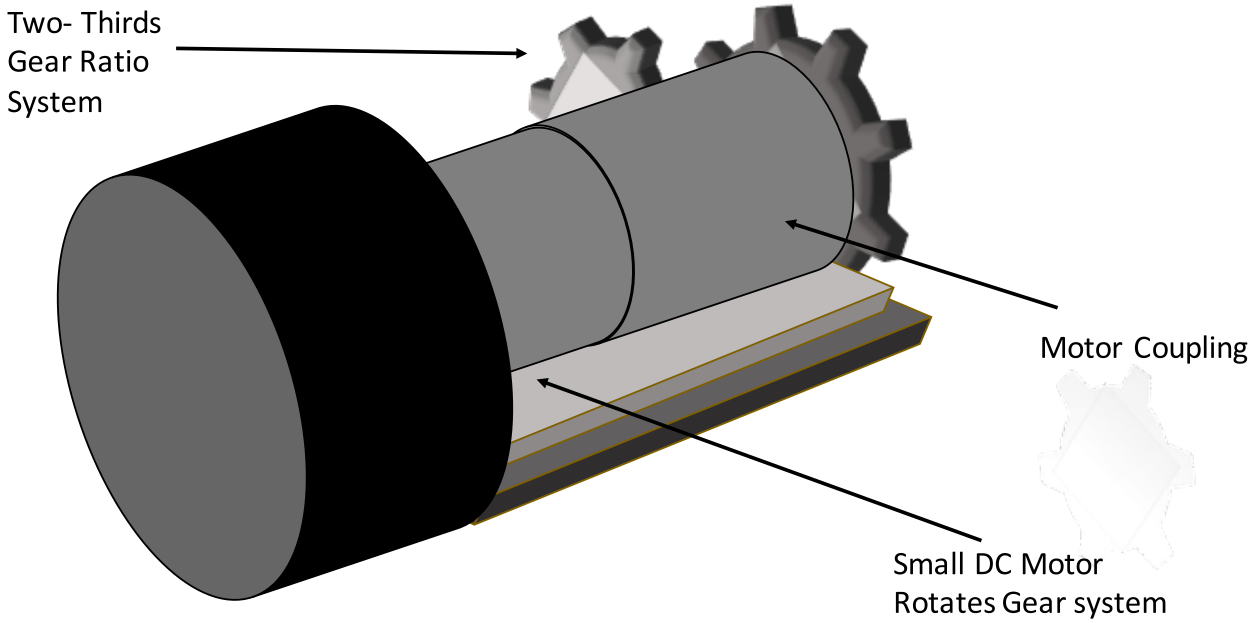
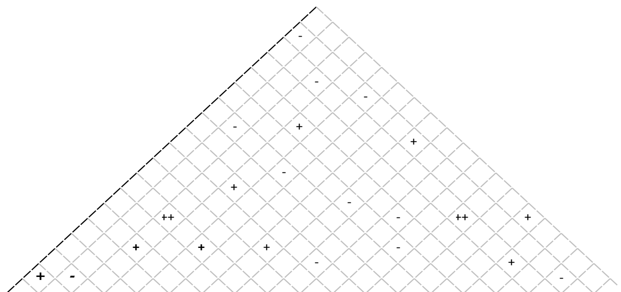


Figure 6. Small DC motor gear system

Table 1. House of Quality

Legend		
◉	Strong Relationship	9
▣	Medium Relationship	3
△	Weak Relationship	1
▲	Maximize	
▼	Minimize	
x	Target	
++	Strong Positive	
+	Positive	
-	Negative	
--	Strong Negative	



Importance	Customer Requirements \ Engineering Characteristics	Height (inches) of Robot	Length (inches) of Robot	Width (inches) of Robot	Weight (l) of Robot	Time to Complete Full Run	Gear Ratio of Large DC Motor	Gear Ratio of Small DC motor	Lateral Reach (inches)	Longitudal reach (inches)	Speed to Collect Droids	Speed to Deliver Torpedoes	Time to Open Arms	Time to Close Arms	Distance from Robot to Escaping the Death Star	Total Cost	Assembly Time (h)	Number of Parts	Cylinder's Radius Connected to Gears(inches)	Time Robot Needs to Stops to Deposited Objects	
	Direction of Improvement	X	X	X	▼	▼	▼	▼	▲	▲	▲	▲	X	X	X	▼	▼	▼	▲	X	
7	Height < 18 inches	◉														△					
7	Length < 24 inches		◉		△				▣	▣					△	△					
7	Width < 12 inches			◉					◉		▣				△	△					
6	Total Cost < $100	△														◉		△			
7	Deliver Torpedo's to Death Star	▣	△	△		▣	▣	◉		◉		◉						▣	◉	◉	
6	Collect Force Units		△	▣		▣	△		◉				▣	▣				△	▣	△	
9	Collect Droids			◉		▣	◉		◉	▣	◉	▣	◉	◉				▣	▣	△	
8	Remove TIE Fighters	△	△	△		△												▣	△		
5	Collect Light Saber					△			△				△	△				△	△	△	
9	Escape Explosion		▣	▣		◉	◉							△	◉				▣		
7	Deposited Force Units in Training Zone			▣		◉	◉		▣	▣				▣	▣			△	▣	◉	
9	Operate Autonomously					◉	◉	▣			▣	▣	△	△					△	△	
9	Completes Task in < 30 Seconds					◉	◉	▣			◉	▣	◉	◉	△				◉	▣	
5	Easily Transportable Meaning?	△		△	◉																
6	Structurally Sturdy Meaning?		△	△	◉								◉	◉		△	△				
9	Indicates Start Time					▣	▣	▣				▣	◉	◉						▣	
8	Collect Droids < 3 Seconds					◉	◉		◉	△	◉		◉						◉		
8	Fast Motors					◉	◉	▣			◉	◉	◉	◉	▣	△			◉	▣	
8	Boxes Easily Meaning?	△	△	△				△	▣	▣			△	△							
4	Easy to Disassemble	△	△		▣												▣	▣			
4	Easy to Reassemble	△			▣												▣	▣			
8	y to Manipulate Code According to Functionality					▣	◉	▣	▣		▣	◉	▣	▣	▣		▣	▣	◉	◉	ε Importance:
	Absolute Importance	119	129	244	130	616	657	200	365	167	378	315	505	463	173	89	54	144	475	305	5527
	Relative Importance	).022	).023	).044	).024	).111	).119	).036	).066	).030	).068	).057	).091	).084	).031	).016	).001	).026	).086	).055	

Table 2. Specification Sheet

		Specification for:	Issued:	11/21/17
		Destroying the Death Star	Page 1 of 1	
Changes	**D/W**	**Requirements**	**Responsibility**	**Source**
		Creating an Autonomous Robot to Destroy the Death Star		
		Geometry		
10/24/2017	D	Robot Length ≤ 12 inches	Design Team	Competition
10/24/2017	D	Robot Width ≤ 24 inches	Design Team	Competition
10/24/2017	D	Robot Height ≤ 18 inches	Design Team	Competition
11/04/2017	W	Robot Reaches Objects 6-14 inches in Front	Design Team	Design Team
11/10/2017	W	Robot has a Lateral Reach of 40 inches >	Design Team	Design Team
11/08/2017	W	Torpedo arm > 18 inches	Design Team	Design Team
		Kinematics		
10/29/2017	W	Robot Minimum Speed 0.4 m/s	Design Team	Design Team
10/29/2017	W	Robot Maximum Speed 0.9 m/s	Design Team	Design Team
11/02/2017	W	Wheel Rotation 25 Rev/sec	Design Team	Design Team
10/24/2017	W	Gear Ratio of Large DC Motor at least .5	Design Team	Design Team
11/13/2017	W	Gear Ration of Small DC Motor of at least .75	Design Team	Design Team
10/24/2017	W	Travels a 5-8 inches up	Design Team	Design Team
		Forces		
10/25/2017	W	Friction Force from Wheels < 15N	Design Team	Design Team
10/24/2017	W	Withstand 110 N from Impact	Design Team	Design Team
		Materials		
10/24/2017	W	Number of Servos 3 ≤3?	Design Team	Design Team
11/13/2017	W	Small DC Motor Ran at Max spelling	Design Team	Design Team
10/27/2017	W	Large DC Motor Ran a Max	Design Team	Design Team
10/27/2017	W	Linear Actuator Fully Extended at 5 inches	Design Team	Design Team
10/24/2017	D	Micro Python Pyeborad x1	Design Team	Competition
10/24/2017	D	MotorSheild ?	Design Team	Competition
11/13/2017	W	Assorted Gears x4	Design Team	Design Team
11/13/2017	W	Motor Couplings @ .5 inches x2	Design Team	Design Team
		Signals		
10/28/2017	D	Robot Activates 2 seconds by Relay Switch	Design Team	Competition
		Safety		
	D	Must Not Damage Other Robots or Track	Design Team	Competition
		Disassembly		
	D	Remove From Track in 2 minutes	Design Team	Competition
		Assembly		
	D	Setup Within 4 Minute Time Limit	Design Team	Competition
		Transport		
10/24/2017	W	Weight less than 10lbs, Easily Moveable	Design Team	Design Team
		Operation		
10/28/2017	D	Complete Task in 30 seconds or less	Design Team	Competition
10/24/2017	W	Navigate Autonomously Forwards and Backwards at least 3 ft.	Design Team	Design Team
10/27/2017	W	Arms Swing Out Using Linear Actuator Extended at 5 inches	Design Team	Design Team
10/28/2017	D	Turns Off After 30 Seconds of Running Code	Design Team	Competition
		Maintenance		
11/14/2017	W	Simple Code Between 80-100 lines	Design Team	Design Team
		Costs		
10/25/2017	D	Cost Materials < $100	Design Team	Competition
		Schedules		
	D	Operating Robot Completing all task by November 21st	Design Team	Competition

Rotate 180°

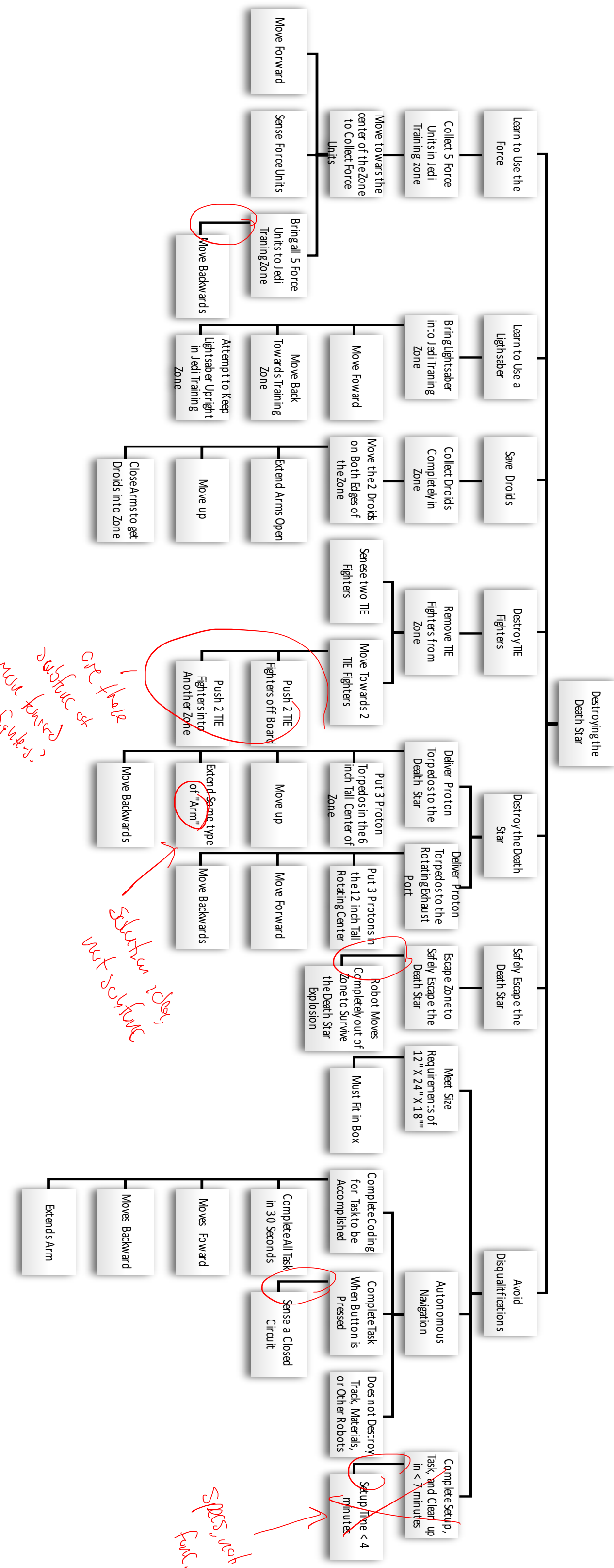
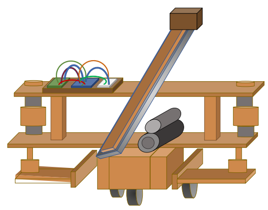
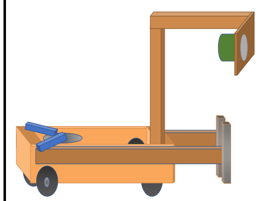
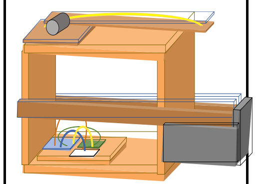


Figure 7. Function Tree

move other alt. designs

Table 3. Third-Level Evaluation Matrix

Importance:	Customer Requirements:			
9	Height < 18 inches	9	9	7
9	Length < 24 inches	8	8	8
9	Width < 12 inches	9	6	7
9	Total cost < $100	9	9	9
7	Deliver Torpedoes to Death Star	8	7	9
8	Collect Force Units	8	8	9
6	Collect Droids	10	7	6
8	Remove TIE Fighters	9	6	7
4	Collect Light Saber	5	5	7
7	Escape Explosion	7	7	7
8	Deposit Force Units in Training Zone	6	7	4
9	Operate Autonomously	9	9	9
7	Completes Task in < 30 sec	7	7	7
5	Easily Transportable	4	7	4
5	Structurally Sturdy	8	8	9
5	Indicates Start Time	6	5	5
9	Complete Run in < 30 sec	9	8	6
6	Collect Droids < 3 sec	10	6	8
8	Fast Motors	9	7	7
6	Boxes Easily	10	9	7
4	Easy to Manipulate Code According to Functionality	5	4	8
3	Easy to Disassemble	3	8	8
4	Easy to Reassemble	6	7	8
ABSOLUTE TOTAL:		**1230**	**1132**	**1114**
RELATIVE TOTAL: **Absolute Total/ Max Possible**		**0.79**	**0.73**	**0.72**

0- Unsatisfactory	**1- Inadequate**	**2- Weak**	**3- Tolerable**	**4- Adequate**	**5- Satisfactory**
6- Good, but draw backs	**7- Good**	**8- Very Good**	**9- Exceeds Requirements**	**10- Ideal Solution**	

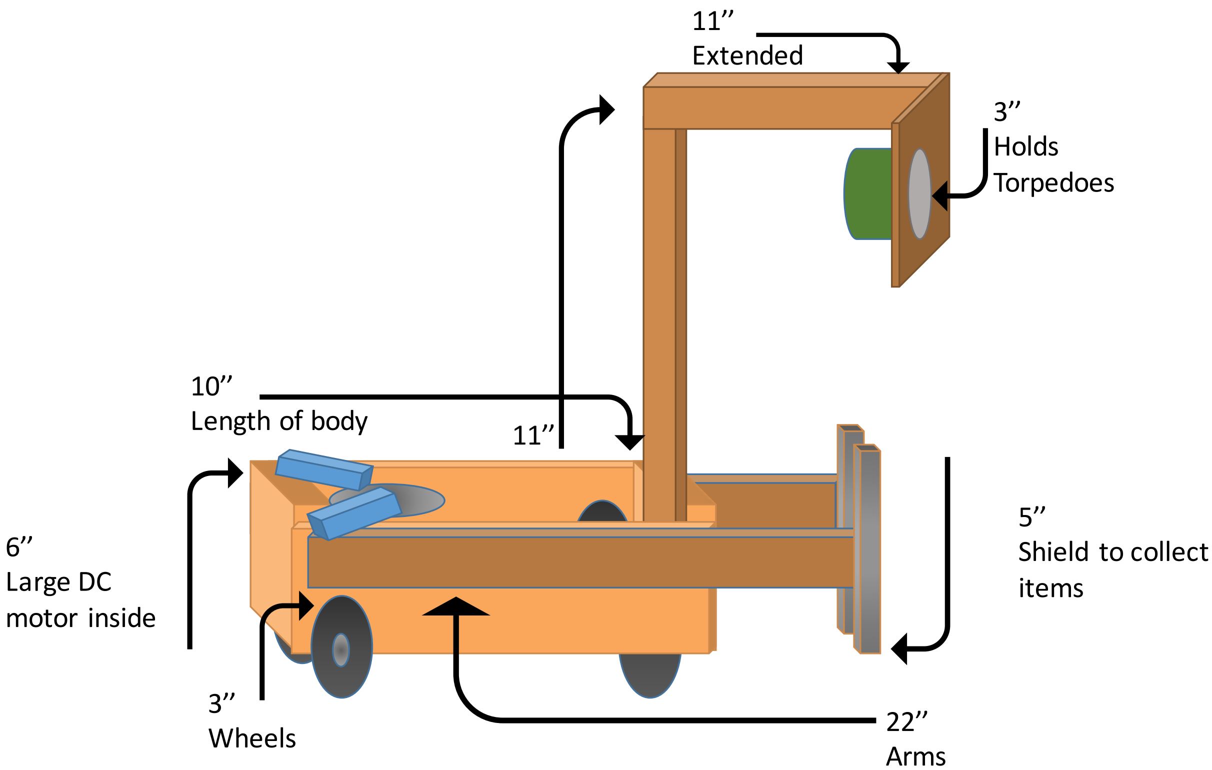


Figure 8. First Alternate Design

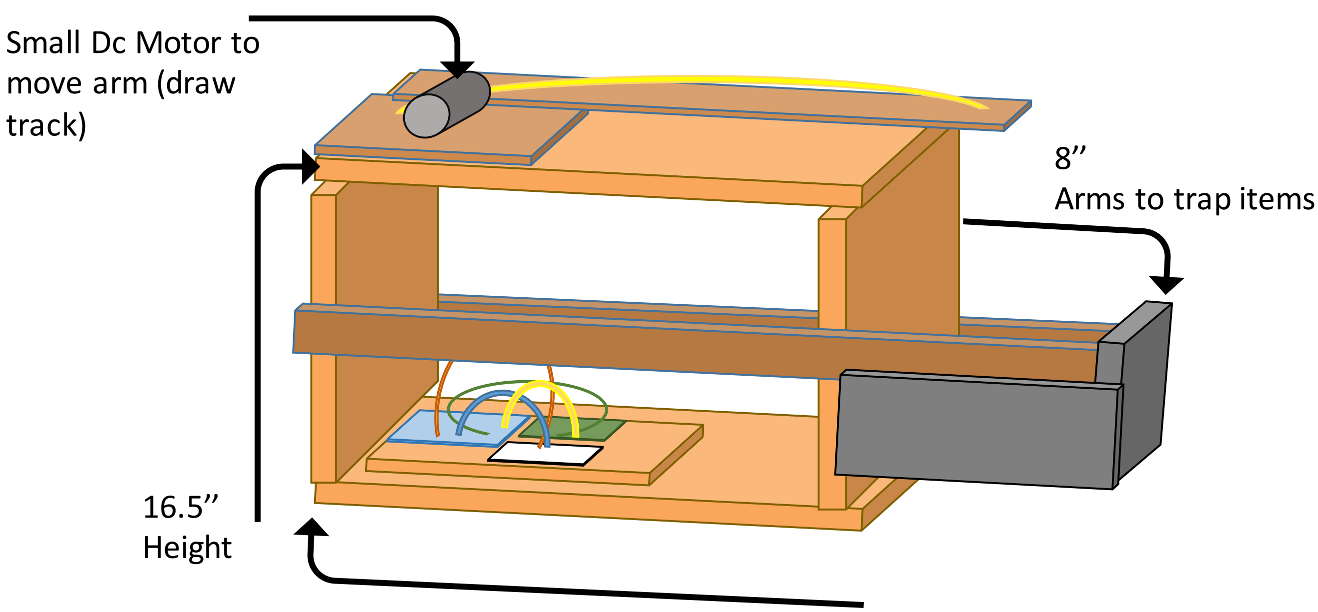


Figure 9. Second Alternate Design

Torpedo holder

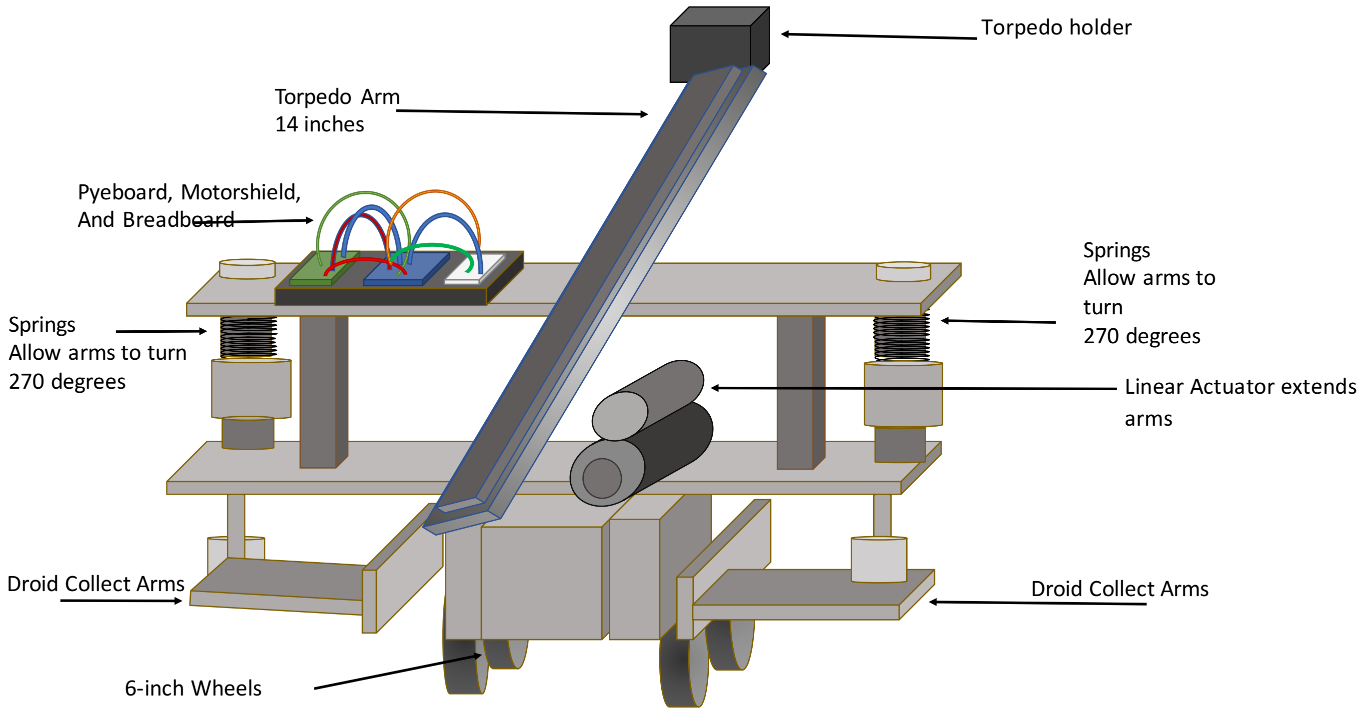


Figure 10. Final design, prototype 2