Final Project: Final Report

MCHE 201: Introduction to Mechanical Design

Fall 2017

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Abstract

The Star Wars Contest is a robotics competition that requires student-built robots to compete in a head to head competition on a representation of the Star Wars galaxy. A rebel force has formed to defeat the Empire and Emperor Palpatine, but needs help from MCHE 201 students. Due to competition restrictions and rules such as dimension restraints, and a thirty-second time limit, it is difficult to complete all of the tasks. To help with completely understanding the challenges of the competition and simplifying main tasks, certain design tools were used such as a House of Quality, a Specification Sheet, and a Function Tree. After completing an overview of possible designs, the MSE-6s was chosen. The MSE-6s uses a triple decker design with three wheels to overcome obstacles in the galaxy and escape the Death Star explosion. The design uses an extending grabber arms to collect Force Units, the Lightsaber, save the droids, and destroy the TIE Fighters. Proton Torpedoes are delivered to the Death Star by a dropping arm on the top level. The MSE-6s performed well in the competition coming in seventeenth place. This report presents the complete design process and evaluates the results of the Star Wars competition.

Good

could mention judging too

I. Introduction

The Star Wars competition requires teams to design and build a device to battle on the Star Wars Galaxy track. Each robot is placed in a start zone, where it must be boxed before competing to ensure that it does not exceed the competition restrictions. Various tasks must be accomplished within each team zone, and the device is expected to return to the start zone within the thirty-second time limit. The tasks include transporting five Force Units (foil-wrapped table tennis balls) from the team zone to the team's Jedi Training zone, each of which will award the team five points. Another task is for the device to place a Lightsaber (toy bowling pin) in the team's Jedi Training area. If the Lightsaber is completely in the Training zone and remains upright, the team will be awarded ten points. If it is completely in the Training zone but tips over, the team will be awarded five points. The device must also save the Droids (plastic toy blocks), which are located at the edges between the team zones. For each Droid that is completely collected into the team's zone, the team will earn five points. Another mission is to destroy the two TIE Fighters (sponges) by completely removing them from the team zone. If they are not completely removed from the team zone, the team will be penalized ten points per TIE Fighter. These missions created challenges when designing a device to branch out and collect or remove these objects, while having to start in a confined volume. The device must also destroy the Death Star by dropping three Proton Torpedoes (small LED keychains) into the Death Star for a possible five points per Torpedo, or to drop them into the rotating Exhaust Port for a possible ten points per Torpedo. This required the design of the robot to possess the capability of reaching the Exhaust Port while starting at some distance away. Finally, the device must escape the Death Star explosion by driving completely out of the team's zone and back to the start zone at the end of the thirty-second trial. If this task is completed, the team will be awarded twenty points. This is a challenging problem when designing the robot to accomplish each of the other missions while only having thirty seconds to do so.

stay formal

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The Star Wars contest challenges not only challenges students during the competition, but also during the design and build process of the robot. Challenges come when deciding the best design plan that is capable of achieve the different goals. For example, all teams start at a same maximum volume and distance away from the Exhaust Port, but there are many ways to utilize that volume and include added-on parts to deliver the Proton Torpedos. The House of Quality, Specification Sheet, and Function Tree help understand the problems of the contest by analyzing specific requirements, numerical targets, and tasks. Project planning and team management are also important challenges in completing the Star Wars mission. A Prioritization Matrix, a Gantt Chart, and a Responsibility Chart were completed to distribute certain tasks, responsibilities, and set goals amongst different members of the team to achieve the customer requirements. Focusing on these competition and design challenges help to make the finished product's performance significantly better. Three design concepts were designed to compete in the competition, with the MSE-6s chosen as the final design, scoring a 2,353 through a thorough

focus on eng. challenges, not challenges for the team.

analysis of a Third-level Evaluation Matrix. In Section II, the final design will be reported conceptually by describing its functionality and aesthetics. A concise summary of the problem understanding phase will be explained, along with an analysis of the design tools that were created in Section III. Section IV will demonstrate the alternate designs in a concept evaluation section, with a detailed analysis of the Third-level Evaluation Matrix. The analysis of the robot's performance is covered in Section V. Finally, Section VI concludes the report with a detailed summary.

II. Final Design

The final design for the Star Wars competition, the MSE-6s as seen in Figure 1, is aesthetically modeled after the MSE-6 Mouse Droid from the Star Wars movies. It is designed to complete the various tasks of the competition using different engineered components. The MSE-6s uses a triple-decker design, in which each level serves its own purpose. The Base Board, as seen in Figure 2, is the base of the design and located at the bottom of the assembly. The Base Board has specific cutouts for the wheel motor, the drive wheel, the breadboard, and the pyboard, which are used to hold the components in place. There are two hinges located at the front edge of the Base Board, which are used to hold the Grabber Arms in place and allow them to open and close. The Grabber Arms are designed so that they extrude far enough from the Base Board to be able to grab and hold the game pieces such as the Lightsaber or the Force Units. The second level of the design is used to mount the Linear Actuator, which is used to open and close the Grabber Arms. The third level of the MSE-6s is used to mount the Proton Torpedo Dropping Arm at a height above the exhaust port. This arm is used to hold the Stepper and Servomotor assembly that functions as a lever to drop the Torpedos. good

The MSE-6s consists of a three-wheel design, in which only the front wheel is powered by a large DC motor. The rear wheels are screwed to the back of the assembly and only allowed to free spin linearly. Although this design limits the mobility of the device by allowing it to only drive forward or backward, the Grabber Arms are designed to complete the tasks that would otherwise be neglected by devices that cannot turn. The Grabber Arms, seen in Figure 3, are positioned in the front of the Base Board, and make use of the Linear Actuator to function. The Linear Actuator is attached to the bottom of the second level of the device, and to the top of the Grabber Arms with an engineered hinge mechanism built of measured wood pieces. This allows the Grabber Arms to open and close as the Actuator extrudes causing the MSE-6s to grab anything in its path. The Grabber Arms are designed to grab and relocate the Lightsaber, the Force Units, the Droids, and to destroy the TIE fighters by sweeping them out of the Team Zone. good

To destroy the Death Star, the Proton Torpedo Dropping Arm is used, seen in Figure 4. This arm is placed on the third level of the device, and its sole purpose is to hold and drop the Torpedos at a height above the rotating Exhaust Port, as illustrated in Figure 5. An extension piece is fitted at the end of the arm and is rotated by employing the use of a Stepper motor. Attached on the end of the extension piece is a Servomotor that holds the Proton Torpedoes in place. With the data obtained from an IR distance Sensor fitted beneath the extension arm, the stepper motor swings the assembly out until it detects that it is over the rotating exhaust port. The IR Sensor is also used to detect when the port has rotated directly below it, and triggers the Servomotor to drop the proton torpedoes. good

As for destroying the Tie Fighters, the MSE-6s is equipped with two deployable flaps located on the outward facing sides of the grabber arms that rotate perpendicular to the device's facing to extend its sideways reach. On its return from destroying the Death Star, the MSE-6s deploys these flaps to brush off the two sponges from the arena, while also escaping the Death Star explosion.

One of the key points in the development of the MSE-6s is in the methodization of its coding. The device is programed heavily with the use of functions that help to simplify the body of the code and the fine-tuning during testing. The capstone of this feature is the way in which forward and backward movement is controlled. Typically, the coding behind controlling the onboard motors used for locomotion is to issue a command that controls the motor's speed and direction, then issue another command that causes the processor to delay continuing a certain amount of time, and finally command the motors speed back to zero. This requires much more typing, lines of code, and guess work than is necessary. The method used to control movement on the MSE-6s is a function of distance rather than time. Through the algorithm shown in Figure 6, a function is called by the user that passes a value of distance in inches, and using the velocity equation with a measurement of the average velocity the device travels at a certain voltage; the time needed for the motor to operate to achieve that given distance is automatically calculated, and the operation executed. good

III. Problem Understanding

To be successful in the Star Wars competition, a complete understanding of the engineering challenges and problems that arise is necessary. Completing certain design tools such as the House of Quality, the Specification Sheet, and the Function Tree, are essential to having a complete understanding of these problems. The challenges range from understanding the customer requirements and goals of the competition, to simplifying complex problems that occur during the different tasks, as well as needing to conceptually design and build a device. As seen in the HOQ in Table 1, The competition requires ~~students to design and build~~ the ~~a~~ device that operates autonomously, meets dimension restrictions of being within two feet long by one foot wide by eighteen inches tall, and ~~to~~ completes the various tasks that earn the team points. For example, the device must completely remove the TIE Fighters from the team zone. This is the only mission that results in a penalty of negative points if it is not completed. For this reason, removing the TIE Fighters is regarded as one of the most important customer requirements, and is placed into the House of Quality to determine which engineering characteristics should be maximized to meet this requirement. The amount of coding used, the average number of tasks completed, and the average number of points scored across trials are examples of the most important engineering characteristics. By maximizing these characteristics, the device should be successful in satisfying the most important customer requirements. The number of tasks completed deemed to be the most important engineering characteristic, scoring a relative importance of fifteen percent when compared to the other characteristics. With this information, it is crucial that the device be constructed to maximize this characteristic for it to be successful. The House of Quality can be seen in Table 1.

good

Reference earlier in paragraph

The Specification Sheet, in Table 2, is used to organize engineering characteristics and customer requirements into subcategories, and to determine whether they are considered a demand or a wish. This helps with problem understanding because the organized table ensures demands are being satisfied, along with wishes that have been set upon. For example, in the assembly subcategory of the Specification Sheet, the contest rules require that the device be set up for the trial in less than three minutes and forty-five seconds. This is documented as a demand in the Specification Sheet because if this requirement is not met the device will be disqualified from the competition. To combat this, a wish that the device be set up in less than three minutes and thirty seconds is included. By achieving this wish, it would ensure that the device would be allowed to compete and not be disqualified.

ok

The Function Tree, as seen in Figure 7, is used to simplify complex problems that arise in the Star Wars competition. This is critical to problem understanding as it simplifies these complex challenges into smaller, easier to solve problems. For example, the competition presents the task of relocating the Force Units from the Team Zone and into the Jedi Training Zone. This is a complex problem as the robot must know how to find and grab the Force Units, and know where to drop it off before it returns to the Start Zone. The Function Tree reduces the complexity of this problem by simplifying it into smaller steps. Relocation of the Force Units requires an average distance measurement from where the device starts to the Force Units. The MSE-6s must also know how to navigate to and from the Force Units, using smaller steps such as move backwards and forwards. For the device to grab the Units, a distance code function must be applied, with a time delay while a grab code function encloses the Force Units for movement.

ok

IV. Concept Evaluation

Three distinctive design concepts were considered for the Star Wars competition, the MSE-6s, the Scoop Bucket, and the T-Rex. Although the MSE-6s was chosen as the final design, the Scoop Bucket and the T-Rex were thoroughly analyzed as possible design choices. The Scoop Bucket, as seen in Figure 8, is designed with a three-wheel design and a grab arm function. It uses a rear powered drive wheel, with two linear free spinning wheels in the front of the device for movement. The Force Unit Scoop, as illustrated in Figure 9, is hinged to the body and acts as the arms of the Scoop Bucket. As the name implies, this scoop design is only able to grab and relocate the Force Units. It is also designed so that it hugs the outer rim of the Death Star upon impact. This allows the sliding Proton Dropping Arm to extrude far enough to reach the Exhaust Port, allowing the Proton Dropping Pin to drop the Torpedos into the opening and destroy the Death Star. The extruded Proton Dropping Arm is illustrated in Figure 10, which simulates how the device would approach the Death Star. The Scoop Bucket also has a hinged Lightsaber Holder that is powered by a Servomotor. The Servomotor pushes the Holder upwards to take on the Lightsaber, and then drops it so that it hugs the Lightsaber tightly as the device continues to navigate and complete the tasks. good

Design Concept Three, the T-Rex as seen in Figure 11, acts as a hugging device. The T-Rex consists of a three-wheel design, with one main wheel in the front and two wheels in the back. These wheels are used to drive the T-Rex to the Exhaust Port while collecting droids and Force Units. The T-Rex has far reaching grabber arms that are hinged to the rear of the device, seen in Figure 12, and operated by the Linear Actuator. The longer arms allowed the T-Rex to easily save the Droids as the extended reach could reach into other Team's Zones, which can be seen in Figure 13. A cylinder is connected to the roof of the device's body. This cylinder is used to drop off Proton Torpedos. The T-Rex, however, does not have any functions for removing the TIE Fighters which introduces downfalls to the design. good

These alternative designs had many strong suits, but they did not satisfy the maximum amount of customer requirements. The Third-level Evaluation Matrix helped compare the strengths and weaknesses of the alternative designs to the MSE-6s based on a ten-point scale. The customer requirements were listed in one column, along with its importance rating in another column. The designs were given a score from one to ten, based on how well each design met each customer requirement. It can be seen in Table 4, that the MSE-6s totaled the most points with a score of 2,353 by satisfying the most important customer requirements. It came down to the robot's performance in each category of the contest. The MSE-6s Grabber Arms extend far enough to reach the droids while its deployable flaps knock off the TIE Fighters during the escape of the Death Star. Although the Scoop Bucket has a convenient Lightsaber Holder, the bucket's variation of the Grabber Arms on the MSE-6s had restrictions of only being able to grab and relocate the Force Units. Initially, the T-Rex design seems to satisfy problems the MSE-6s has with its shorter reach. However, after more evaluation of the T-Rex plan, it was observed that the arms would tend to drop and catch the floor, causing the device to lose control. Another assumption was that the longer reach could possibly catch the arm of another device, causing the T-Rex to turn and lose sense of direction. This problem was unsolvable as with only three linearly operating wheels, there was no way to correct its path. Due to the MSE-6s having the capability of accomplishing several of the most important customer requirements, such as good

stay formal

removing the TIE Fighters and collecting the Droids, it was chosen as the best design to move forward with.

V. Design Performance Evaluation

The MSE-6s did score very well in the judging portion of the competition, placing sixth overall. The judges were able to clearly follow the intended plan of the device. All aspects of the robot were covered, and the design offered a solution to each one of the questions the judges had. The judges also took note of the detailed aesthetics of the robot. A router was used on the base deck to make specific engravings for the pyboard, Motor Shield, and large DC Motor to fit into. The triple-decker design was also useful in concealing wires, making the device more visually appealing. Although the device was not painted, Star Wars stickers were added to go along with the theme of the contest.

points?

Throughout the entire design process, many assumptions were made correct while other times they were not. One correct assumption made was that it was critical for the device to remove the TIE Fighters since not doing so would result in negative points. However, an incorrect assumption made was thinking the device would consistently complete this task once the flaps were incorporated into the design. During the final competition, it was observed that other robots could extend out far enough to knock the MSE-6s off its linear path. If assumptions would have been made correctly, a solution to the problem would have been to make the flaps stronger and longer to ensure that it would still knock off the TIE Fighters in the case of the robot deviating from the intended path. Another incorrect assumption was that the grabber arms had enough distance to come into contact with the Droids. If this had been more thoroughly considered, design changes would have been made to make the short wingspan of the grabber arms much wider.

ok

Due to these incorrect assumptions, the MSE-6s did not always perform to the best of its ability. The inconsistency with the flaps and the inability to turn if it was misdirected led to losing rounds. The MSE-6s lost two of the three rounds due to these issues as it was not able to complete the tasks at hand once it was knocked off course. However, it did win the first round of the competition by placing second out of the four teams competing. The MSE-6s tied for seventeenth in the competition out of a total twenty-five places.

VI. Conclusion

The Star Wars competition brings many challenges for engineering students. Participants must design and construct a device that not only meets the design regulations in the competition rulebook, but also completes the various challenges that are set by the competition. Through completing a thorough problem understanding phase using a House of Quality, a Specification

Sheet, and a Function Tree, it is possible to confidently devise solutions for issues and pinpoint certain aspects that needed to be incorporated into the design. These tools assisted in the conceptual design of three unique concepts, the MSE-6s, the Scoop Bucket, and the T-Rex, all of which had their own advantages and disadvantages. A Third-Level Evaluation Matrix allowed for the three distinctive designs to be more objectively ranked, and the MSE-6s was ultimately chosen to compete. The device finished tied for seventeenth out of twenty-five. There were areas in need of improvement, but the MSE-6s certainly performed satisfactorily, consistently achieving the goals it was designed and programmed for.

Good

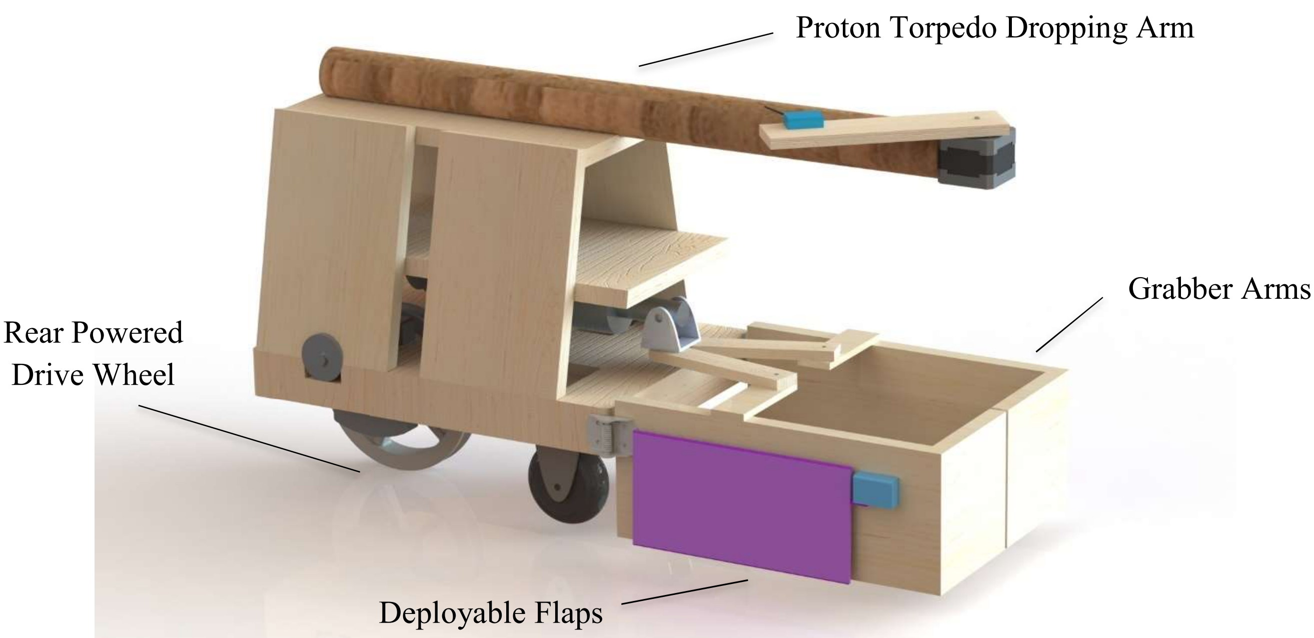


Figure 1: MSE-6s (Final Design)

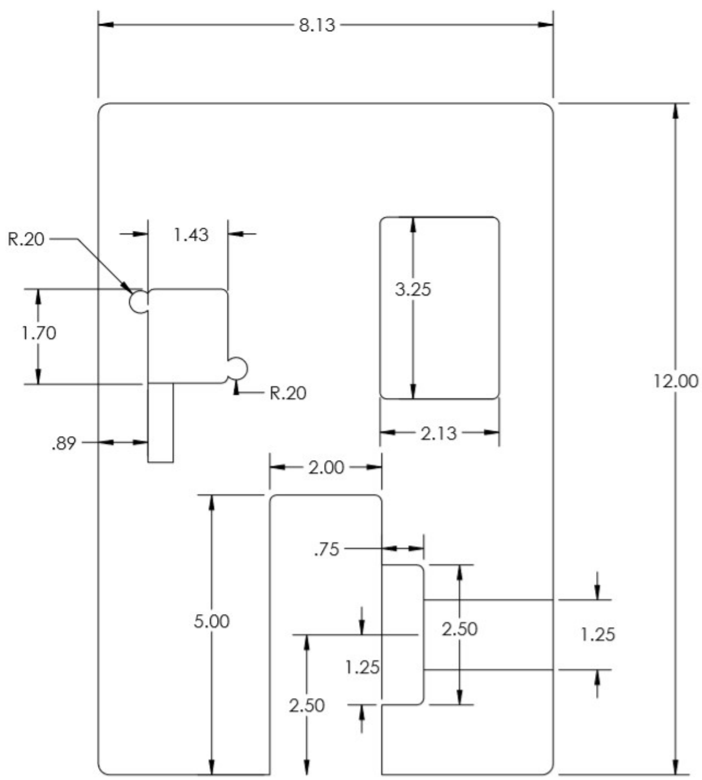


Figure 2: Base Board Cutouts

Good

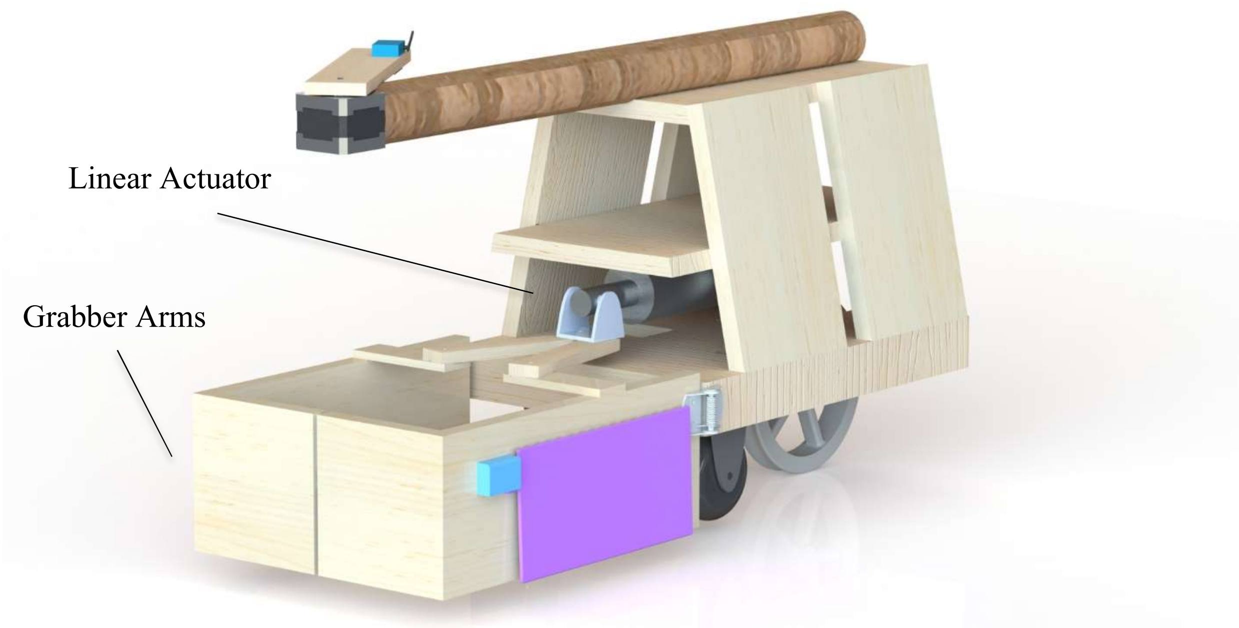


Figure 3: MSE-6s (Front View)

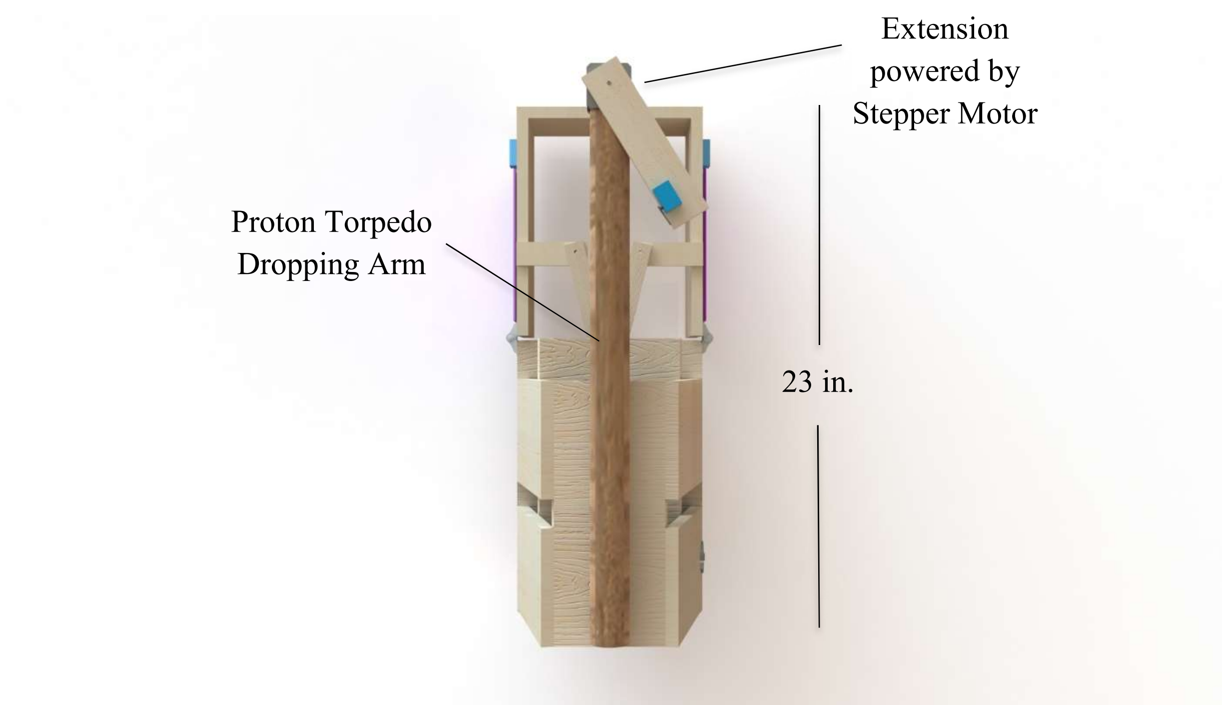


Figure 4: MSE-6s (Top View)

Good

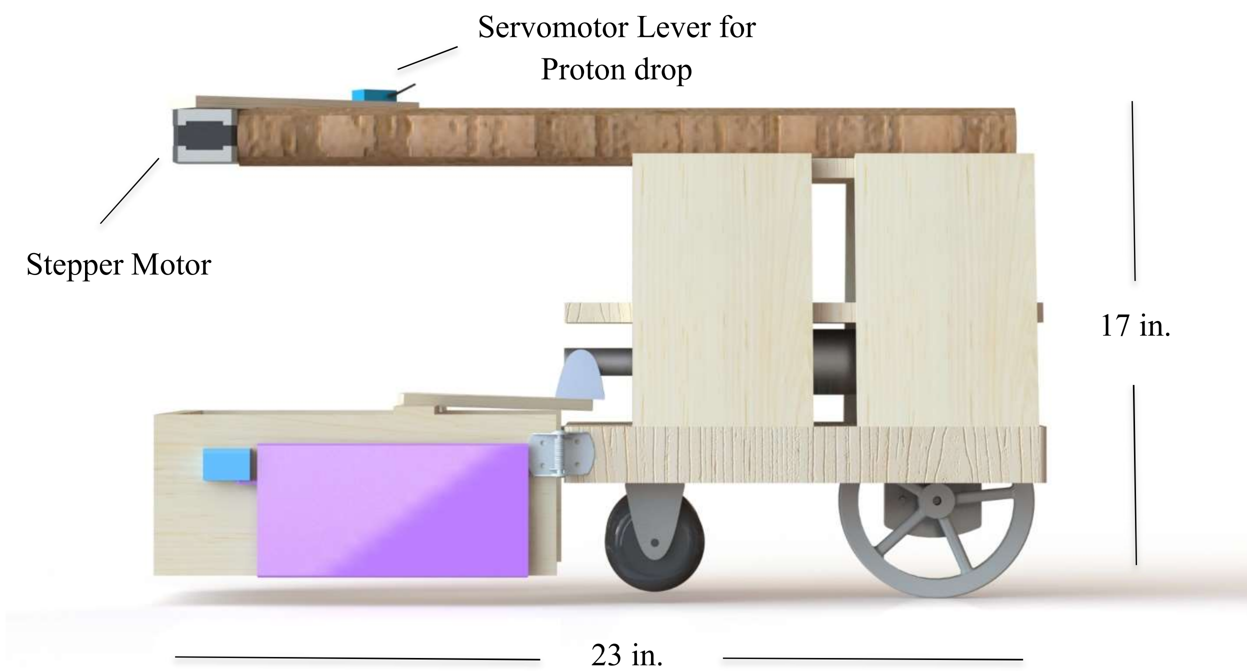


Figure 5: MSE-6s (Side View)

```
def ForwardFull(x):

    timecalc = x / 12.5
    motors.speed(LargeDC, 2500)
    time.sleep(timecalc)
    motors.speed(LargeDC, 0)
```

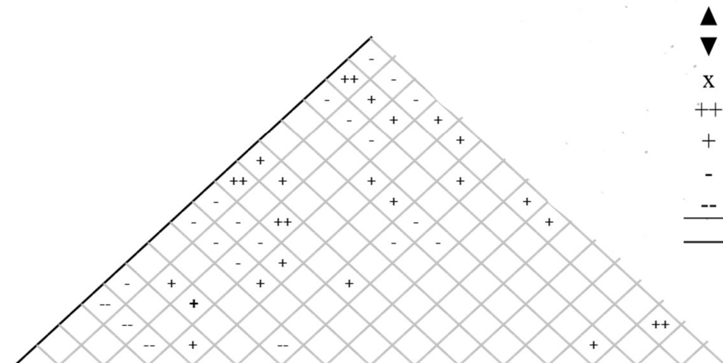
inserting some commenting would help your reader

Figure 6: Algorithm

Table 1: House of Quality

Key of Symbols

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



Importance	Customer Requirements \ Engineering Characteristics	Length of Completed Device	Width of Completed Device	Height of Completed Device	Weight of Completed Device	Total Cost	Number of Task Completed	Time Needed to Complete Each Task	Time Needed to Set Up	Time Needed to Take Down	Distance Device moves from Start Zone to Death Star	Distance the Device can Move on the Track	Amount of Coding Used Measured how?	Number of Electrical Parts	Time Needed to Build	Average Number of Points Scored	Number of Parts
	Direction of Improvement	▲	▲	▲	▼	▼	▲	▼	▼	▼	▼	▼	▼	▼	▼	▲	▼
10	Autonomously Operate						●					▣	●	●		▣	
10	Compete for 30 seconds						▣	●	▣	▣			▣			▣	
10	Clean up within 2.5 minutes				▣			▣	Δ	●				▣		Δ	
10	Length Less than 1 foot	●			Δ	Δ	Δ				▣	Δ		▣			
10	Width Less than 2 feet		●		Δ	Δ	Δ					Δ		▣			
10	Height less than 18 inches			●		Δ	Δ				▣						
10	Device can not bloom out	▣	▣	▣							Δ						
9	Device must be safe				▣							Δ		Δ			
10	Cost Less than $100					●								Δ	▣		▣
10	Set up in 3 minutes and 45 seconds	Δ	Δ	Δ	▣			▣	●	Δ				▣			Δ
10	Collect Force Units	▣	▣	Δ		Δ	●	▣					▣	▣		●	
9	Collect Lightsaber	▣	▣	Δ		Δ	●	▣					▣	▣		●	
8	Collect Droids	▣	▣	Δ		Δ	●	▣					▣	▣		●	
10	Remove TIE Fighters	▣	▣	Δ		Δ	●	▣					▣	▣		●	
10	Deliver Proton Torpedo to Death Star	▣		▣		Δ	●	▣			●	Δ	▣	▣		●	
10	Finish outside of the team's zone	▣	▣				●	●			Δ	▣	▣	▣		●	
10	Gain maximum amount of points	▣	▣	▣		Δ	●	●			▣		Δ	Δ	Δ	●	
7	Withstand Multiple Runs				▣	▣								Δ	▣	▣	▣
10	Cannot permanently change competition area				●										Δ	Δ	
6	Quick Set Up Time on the Track	Δ	Δ	Δ	▣				●	Δ				▣			Δ
10	Does not leave Materials Behind					▣		▣		▣				Δ	Δ	Δ	
6	Stay in Playing Field	▣	▣					Δ			Δ	●		Δ			
4	Aesthetically Pleasing					●									▣		
4	Overall Lightweight Device	Δ	Δ	Δ	●	▣			Δ	Δ				Δ	Δ		▣
4	Few Number of Total Parts	Δ	Δ	Δ		▣			▣	▣			Δ	Δ	●		●
6	Simple Programing Code Meaning?							▣	▣				●	▣		Δ	
5	Low Number of Electrial Parts					Δ	▣	Δ					●	●			Δ
6	Easy to Transport to Competition Area Meaning?	●	●	●	●				Δ	Δ					Δ		Δ
10	No False Starts						Δ	▣					▣			▣	
10	Stops Running after 30 seconds						●	▣					▣			▣	
	Absolute Importance	417	387	295	326	293	868	590	222	188	206	153	464	522	139	780	126
	Relative Importance	0.07	0.06	0.05	0.05	0.05	0.15	0.1	0.04	0.03	0.03	0.03	0.08	0.09	0.02	0.13	0.02

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Table 2: Specification Sheet

	Specification for:	Issued:	11/21/2017
	Final Design Project	Page 1 of 1	
D/W	Requirements	Responsibility	Source
	Design Robot to Accomplish Specific Goals		
	Geometry		
D	Width less than 12 inches	Design Team	Contest Rules
D	Length less than 24 inches	Design Team	Contest Rules
D	Height less than 18 inches	Design Team	Contest Rules
W	Width less than 11 inches	Design Team	Design Team
W	Length less than 23 inches	Design Team	Design Team
W	Height less than 17 inches	Design Team	Design Team
	Kinematics		
W	Travels Forward 22 inches	Design Team	Design Team
W	Moves Backwards 22 inches	Design Team	Design Team
W	Minimum Speed of 1 m/s	Design Team	Design Team
W	Maximum Speed of 3 m/s	Design Team	Design Team
	Forces		
W	Weight of completed device less than 10lbs	Design Team	Design Team
W	Withstand 50 N of Impact	Design Team	Design Team
	Energy		
D	1 Pyboard Microcontroller	Design Team	Contest Rules
W	Device hold less than 25% of Potential Energy	Design Team	Design Team
	Materials		
W	Less than 100 separate parts	Design Team	Design Team
D	3 or less servo motors	Design Team	Contest Rules
D	1 Pyboard Microcontroller	Design Team	Contest Rules
D	1 Stepper Motor	Design Team	Contest Rules
D	1 Linear Actuator	Design Team	Contest Rules
W	1 Wooden Frame	Design Team	Design Team
	Signals		

Table 2: Specification Sheet (Contd.)

D	Turns on automatically within the 30 seconds of competing	Design Team	Contest Rules
W	Turns on automatically within 1 second of start signal	Design Team	Design Team
D	Turns off automatically within the 30 seconds of competing	Design Team	Contest Rules
W	Turns off automatically in 29 seconds after start signal	Design Team	Design Team
	Safety		
D	Zero Explosive Materials	Design Team	Contest Rules
D	Zero Wanton Destruction done to Competition Arena	Design Team	Contest Rules
D	Zero Wanton Destruction done to Opposing Devices	Design Team	Contest Rules
	Assembly		
D	Set Up in Less than 3mins and 45 seconds	Design Team	Contest Rules
W	Set Up in Less than 3mins and 30 seconds	Design Team	Design Team
W	Less than 10 Set Up Steps	Design Team	Design Team
D	Take down in Less than 2mins and 30 seconds	Design Team	Contest Rules
W	Take down in Less than 2mins	Design Team	Design Team
	Operation		
D	Collect and Place 5 Force Units in Jedi Training Zone	Design Team	Contest Rules
D	Collect and Place 1 Lightsaber in Jedi Training Zone	Design Team	Contest Rules
D	Position Lightsaber Upright in Jedi Training Zone	Design Team	Contest Rules
D	Collect 2 Droids into Team Zone	Design Team	Contest Rules
D	Remove 2 TIE Fighters from Team Zone	Design Team	Contest Rules
D	Deliver 3 Proton Torpedoes to Death Star	Design Team	Contest Rules
D	Complete all task within 30 seconds	Design Team	Contest Rules
D	Shut off within 30 seconds	Design Team	Contest Rules
	Costs		
D	Total Cost of Construction Materials is Less than $100	Design Team	Contest Rules

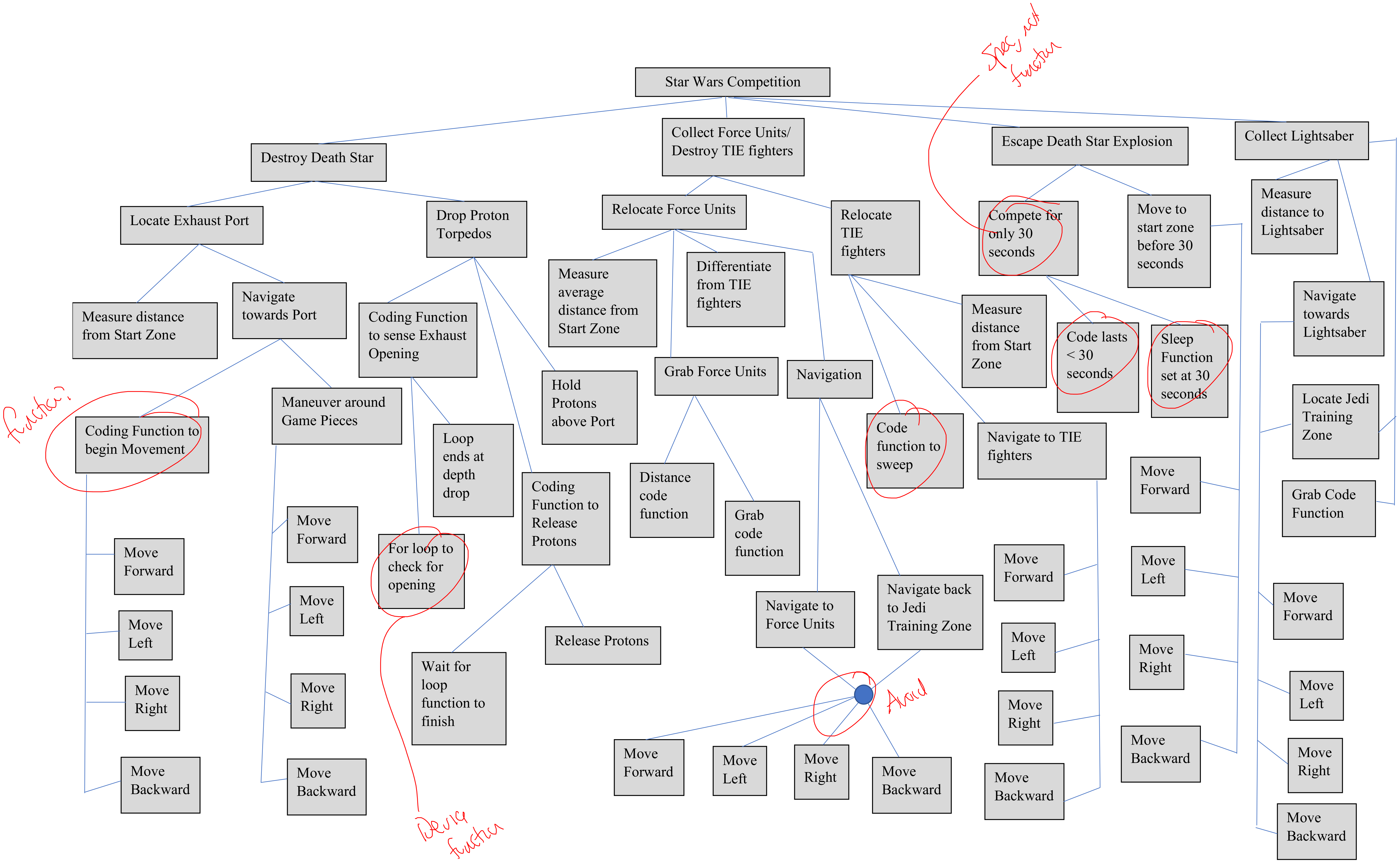

Figure 7: Function Tree

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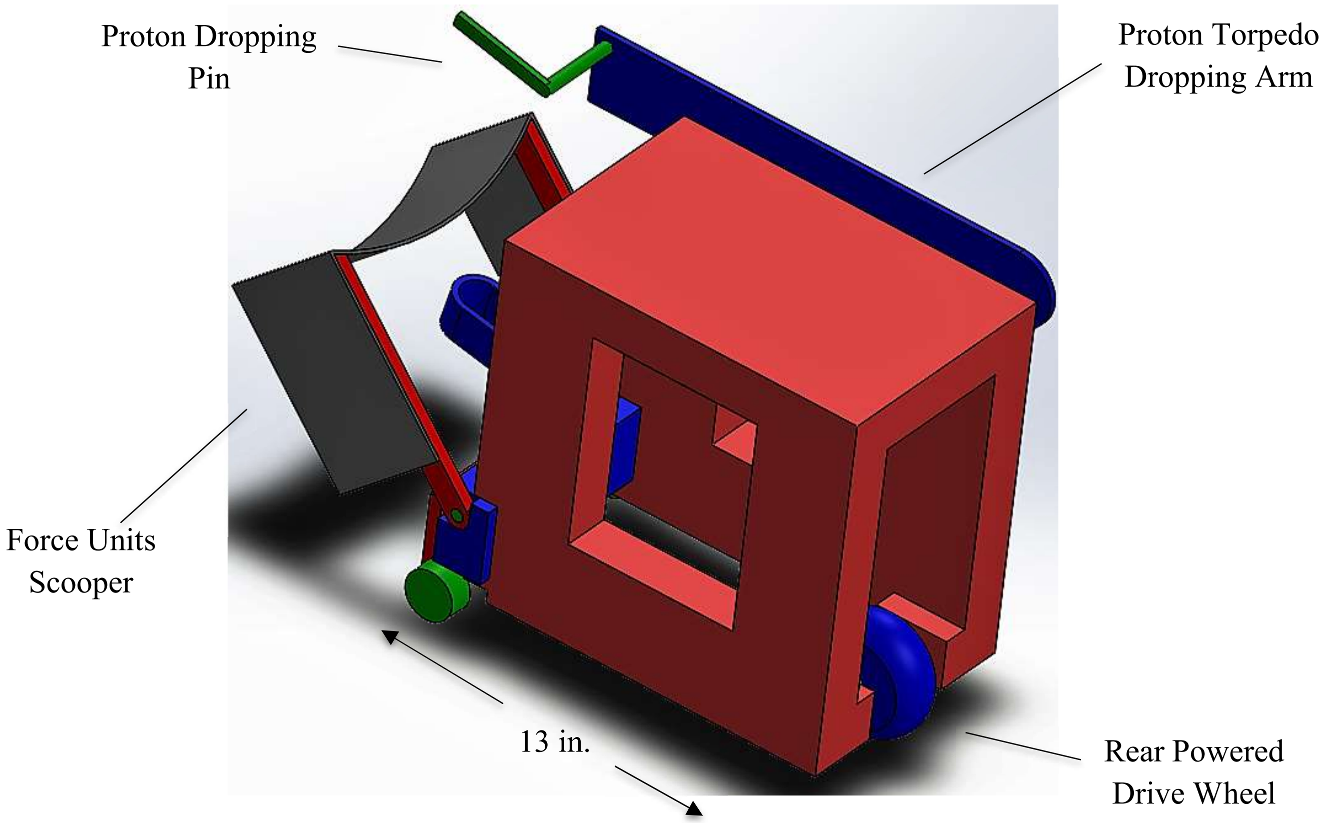

Figure 8: Scoop Bucket

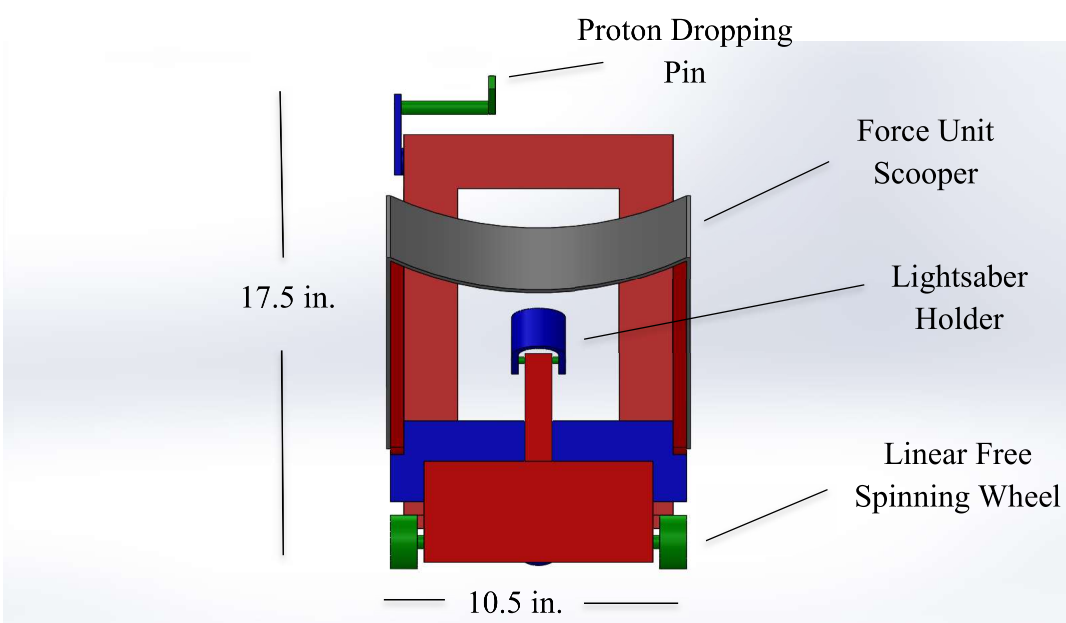

Figure 9: Scoop Bucket (Front View)

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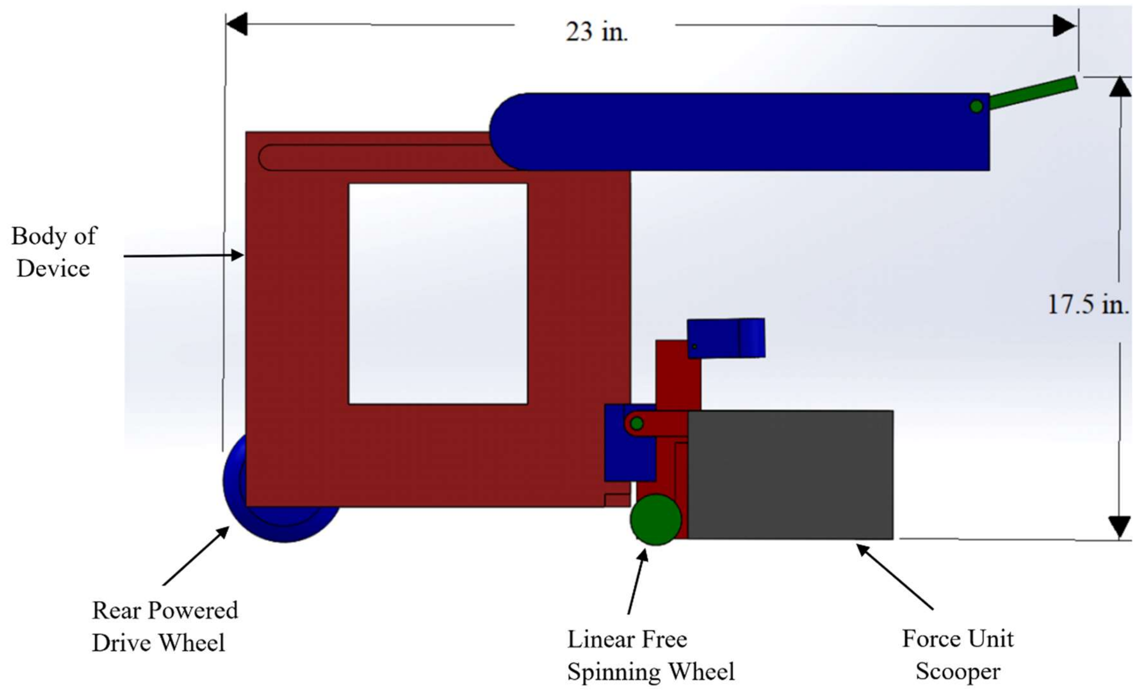


Figure 10: Scoop Bucket Extended (Side View)

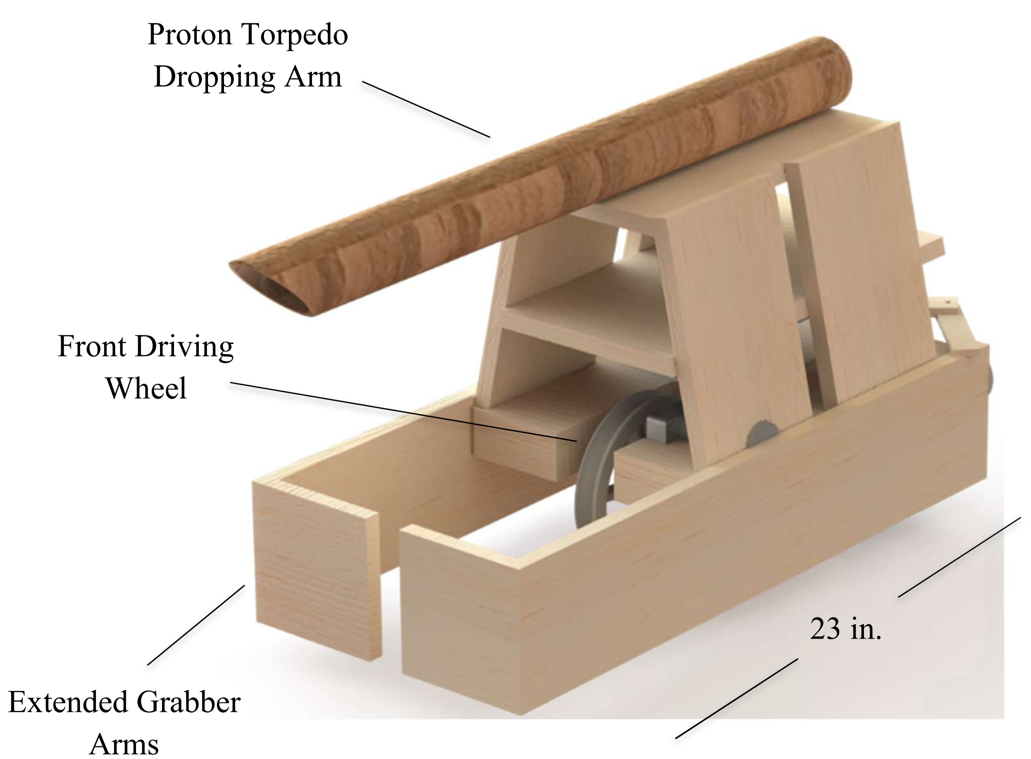


Figure 11: T-Rex

Good

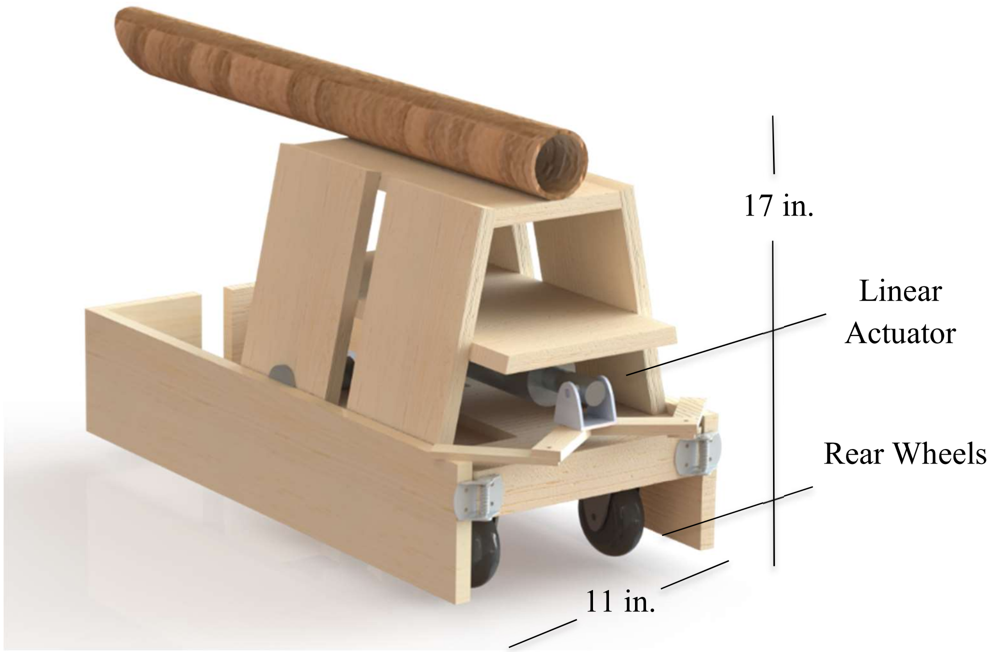


Figure 12: T-Rex (Rear View)

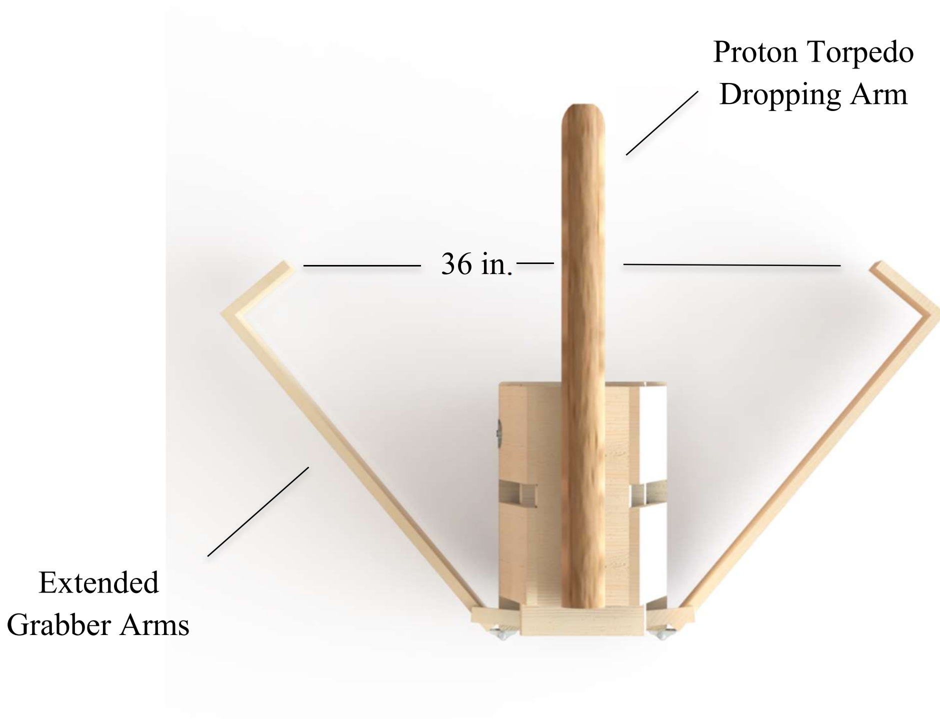
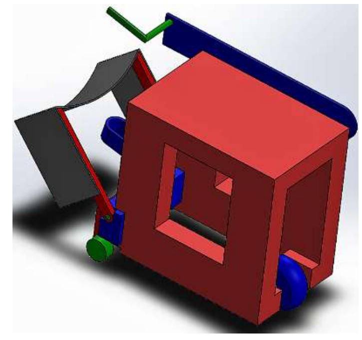


Figure 13: T-Rex (Top View)

Good

Table 3: Third-Level Evaluation Matrix

Importance	Customer Requirements			
10	Autonomously Operate	10	9	10
10	Compete for 30 seconds	9	8	9
10	Clean up within 2.5 minutes	8	10	7
10	Length Less than 1 foot	10	10	10
10	Width Less than 2 feet	10	10	10
10	Height less than 18 inches	10	10	10
10	Device cannot bloom out	9	10	7
9	Device must be safe	10	10	9
10	Cost Less than $100	10	10	10
10	Set up in 3 minutes and 45 seconds	10	10	10
1	Collect Force Units	10	7	8
9	Collect Lightsaber	8	10	8
8	Collect Droids	6	4	9
10	Remove TIE Fighters	9	2	8
10	Deliver Proton Torpedo to Death Star	10	10	10
10	Finish outside of the team's zone	10	10	8
10	Gain maximum amount of points	8	6	9
7	Withstand Multiple Runs	9	9	9
10	Cannot Permanently Change Competition Area	10	10	10
6	Quickly Set Up	10	10	9
10	Does not leave Materials Behind	10	9	10
6	Stay in Playing Field	9	9	8
4	Aesthetically Pleasing	8	9	9
4	Lightweight	7	7	6
4	Few Number of Parts	7	8	7
6	Easily Programed	8	6	8
5	Low Number of Electrical Parts	8	7	8
6	Easily Transported	10	10	10
10	No False Starts	10	10	10
10	Stops Running after 30 seconds	10	10	10
Total		2353	2235	2286
Relative Total= Total/ Number of Criteria		.78	.74	.75