Final Report

MCHE 201: Introduction to Engineering Design
Fall 2017
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Abstract

A robotics competition was assigned to MCHE 201 students that involve designing and building an autonomous robot. The robot can only use gravitational and electrical energy and must fit within a 2'x1'x18'' volume. Excluding given materials, the robot must not exceed $100. Problem Understanding tools such as the House of Quality, Specification Sheet, and Function Tree will be given to determine customer requirements, functions of the robot, and specifications that must be met. The final design will be chosen over the two alternative designs because it is a mesh amongst the two. The Glyder consists of a stationary base and a moving device connected to the base for easy forwards and backwards motion. The swipe arms will knock the TIE fighters and bring in force units and the Lightsaber. The PVC elbow will be used to place the torpedoes in the exhaust port with the help of the infrared sensor. Ultimately, The Glyder placed 17th in the competition and 22nd in the judging part of the competition.

Good

I Introduction

A robotics competition was assigned to MCHE 201 students that involve designing and building an autonomous robot. The robot will compete against other MCHE 201 robots in a Star Wars themed competition. Tasks were given and each task earns a certain amount of points. These tasks include: learn to use the force, learn to use a lightsaber, save droids, destroy TIE fighters, destroy the Death Star, and safely escape the Death Star explosion. The robot has to follow the competition's rules and be built within certain specifications. If any rules or specifications are broken, then the robot will not be able to compete. Engineering challenges include fitting the robot into a 2'x1'x18'' volume, running for 30 seconds or less, staying within a price range of $100, and using a 12V DC motor to power the robot. Understanding the problem is the first and most crucial step to this competition. After understanding the problem, designing the robot is the next challenge. The next section discusses the final design, followed by problem understanding in section III. Section IV discusses concept evaluation, followed by design performance evaluation in section V. Finally, section VI reports the conclusions.

II Final Design

The final design chosen was The Glyder, depicted in Figure 1 and 2. The Glyder has a stationary base and a device that moves forward to the exhaust port and retracts backwards to the base. Shown in Figure 2, extension drawer sliders connect the base to the moving device for an easy track of moving forward and backwards. The extension drawer sliders also help the moving device move straight back to the base and minimize error for it to not get off track. Depicted in Figure 1, the moving device has two drive wheels connected on each side. The drive wheels are on an axle that one of the gears rests on. The DC drive motor is attached to the other gear that sits on top of the gear on the axle. When powered on, the gears turn the axle and rotate the drive wheels to move the device. On top of the extension drawer sliders is PVC torpedo housing, where the torpedoes will be placed. On the side of the PVC torpedo housing is the exhaust port IR sensor that will sense the change in height when the exhaust port rotates, then the torpedo drop servomotor will move the detachable barrier, releasing the torpedoes into the exhaust port. Located in front of the wheels are two TIE fighter slide arms that are powered by the linear actuator. Shown in Figure 2, the slide arms will knock the TIE fighters out of the team zone when the moving device moves forward and then once retracted the slide arms will come in to collect units on the track. The DC drive motor will be run in reverse to escape the Death Star explosion.

III Problem Understanding

Problem understanding tools are used to further understand the customer requirements, specifications, and separate functions of the robot into simpler sub functions. One problem understanding tool used is The House of Quality. The House of Quality shown in Table 1 helps determine the customer requirements and the engineering characteristics that measure the customer requirements. The engineering characteristic, how long does it take to escape the Death Star, measures the time it takes to escape the Death Star explosion. This characteristic is important because one of the customer requirements is to safely escape the Death Star Explosion, and the competition has a thirty second time limit. The correlation matrix correlates each engineering characteristic. For example, the engineering characteristic accuracy of code correlates strongly with the engineering characteristic accuracy of

sensors. The body of the House of Quality determines what the relationship of the customer requirements and engineering characteristics are. Using the relationship it can be determined how important the requirements and characteristics are. Using the relative importance of the relationship helps determine what the most important requirements and characteristics are. Important customer requirements for The Glyder include fitting into a 2'x1'x18'' volume, running for thirty seconds, and costing less than $100. Shown in Table 1, these all received an importance of 9 or 10 because if these are not accomplished, The Glyder cannot compete. Correlating with the important customer requirements are the important engineering characteristics. For example, an important engineering characteristic is operating time. The operating time for The Glyder can only be thirty seconds or less.

The Specification Sheet is another problem understanding tool that lists all of the specifications of the robot. As shown in Table 2, the left column next to the specifications is the want and demand column. Each specification is denoted with a D or W, standing for demand and want. For example, the 1'x2'x18" dimension requirement is a demand whereas making the robot out of 100% recyclable product is a want. The build team is responsible for all of these specifications and the source is either the contest rules or the build team. Changes will constantly be made to the specifications as the problem understanding enhances. The changes column to the left of the demand and want column denotes when changes were made to the robot. Important specifications shown in Table 2 include using one 12V DC motor, up to three servomotors, and one pyboard microcontroller. The Glyder uses all of these materials and it is required to not use more than the specified number of materials. Other important specifications include The Glyder fitting in a 2'x1'x18'' volume, costs excluding fasteners and aesthetics under $100, and operating autonomously for no more than thirty seconds. These specifications coincide with the customer requirements and engineering characteristics of the House of Quality.

The last problem understanding tool used is the Function Tree shown in Figure 3. The Function Tree simplifies functions of the robot from most complex to least complex task. The least complex tasks are all easily completed and build up until the most complex tasks are completed as well. For example, the most complex task is achieving maximum points, which are broken down into each task that will deliver The Glyder points. Then, the function tree is further broken down into simple obtainable tasks such as move, collect force units, and release force units.

IV Concept Evaluation

When considering the competition, various design ideas come to surface. Several conceptual designs are considered; however, only one can be used. During the concept evaluation process, the three best conceptual designs are compared, and the best one was chosen as the final design while the other two were alternatives. The first alternative design is called The Swing Man, shown in Figure 4, has a torpedo swing arm hinged in by tension swing arm string and the string is connected to the DC swing motor. The string starts off in a loose fashion and when the DC swing motor starts to run it tightens the tension swing arm string, which straightens out the arm over the exhaust port. A torpedo hook is connected to the end of the torpedo swing arm, and this is where the torpedoes are placed. The height of the swing arm is adjusted to half an inch over the exhaust port that way the torpedoes will be knocked off the

hook and into the exhaust port once the change in depth has occurred. Another component of this design is the linear actuator swipe arms to knock out the TIE fighters. Tension swipe arm wire is tied to the linear actuator swipe arms. The linear actuator is first compressed and then once powered it pushes forward and creates tension in the wires to move the swipe arms 180 degrees to knock the TIE fighters out. The Swing Man design is stationary, making it easy to retract back into the starting zone by turning the DC swing motor the opposite way and retracting the linear actuator swing arm.

The Tricycle is the second alternative design. As shown in Figure 5, The Tricycle consists of three wheels powered by the DC drive motor. The DC drive motor turns the gear connected to the front wheel which then moves the device. The majority of The Tricycle's body is a frame made of base angle Iron. In front of the frame there are two linear actuator swipe arms. The two linear actuator swipe arms are designed to rotate and destroy the Tie Fighters and then when rotated back in collect as many units as possible to bring back to the Jedi Training Zone. At the top of the frame a linear actuator is used to push a Torpedo extension metal tube forwards and backwards. At the end of the tube is the torpedo drop cup. Attached to the torpedo drop cup is an exhaust port IR sensor. The exhaust port IR sensor senses the change of height in the exhaust port, and a torpedo drop servomotor releases the bottom of the drop cup dropping the torpedoes directly into the exhaust port. The Tricycle then runs everything in reverse in order to escape the Death Star explosion.

The Evaluation Matrix is a tool used to evaluate the two alternative designs and final design against each other. The total and relative total give a clear indication of where each design is ranked. The final design has the highest total due to the better design ideas correlating with how important the customer requirements are. As shown in Table 3, one of the reasons The Glyder was chosen was because it exceeded escaping the Death Star explosion over The Tricycle and The Swing Man.

V Design Performance Evaluation

The Glyder placed 17th place out of 31 robots. The competition was set up as a double elimination tournament. During the first round the Glyder accrued 15 points, resulting in a 3rd place loss. During the second round The Glyder achieved 35 points, resulting in a 1st place win. The third round accrued -20 points, ending in 4th place, eliminating The Glyder. The Glyder also placed 22 out of 31 teams in the judging part of the competition. The mix between a stationary and moving robot appeased the judges and showed the ingenuity of the design.

As shown in Table 3, The Glyder exceeds The Swing Man and The Tricycle at escaping the Death Star. This assumption was correct, resulting in a full escape every round. However, not all assumptions were presumed correct. Although The Glyder was consistent in escaping the Death Star, it was not consistent in any other task. The assumption that it would be consistent in destroying the Death Star and knocking out TIE Fighters was incorrect. The design did not take care of all the inconsistencies that occurred. For example, in the third round the Lightsaber stopped The Glyder from making it to the Death Star and the only task accomplished was escaping the Death Star. One solution to this problem is putting a claw in the front of the robot, run by the stepper motor to open, capture the Lightsaber, and close. Another

incorrect assumption made was underestimating the importance of knocking out the TIE Fighters. As shown in Table 1, the importance was assigned a 6 out of 10. Knocking out the TIE Fighters was very important for the removal of negative points. Thus, the design should've been more thought out. Overall, many design additions and improvements could've been made prior to the competition to mitigate the inconsistencies and help The Glyder live up to its full potential.

VI Conclusion

The design process required understanding the problem and using problem understanding tools such as, The House of Quality, Specification Sheet, and Function Tree. Two alternative designs were given: The Swing Man and The Tricycle. These designs were explained and then evaluated in the Evaluation Matrix which ultimately led to the design chosen. The Final Design chosen was The Glyder ~~because it ranked the highest in the Evaluation Matrix when compared to the two alternative designs~~.The Glyder consists of a stationary base and a moving device to help with guide the retracting robot straight back to the start zone. Unfortunately, The Glyder was flawed and some assumptions that were made turned out to be incorrect. The design placed 17th overall in the competition and 22nd in judging, showing some room for improvement.

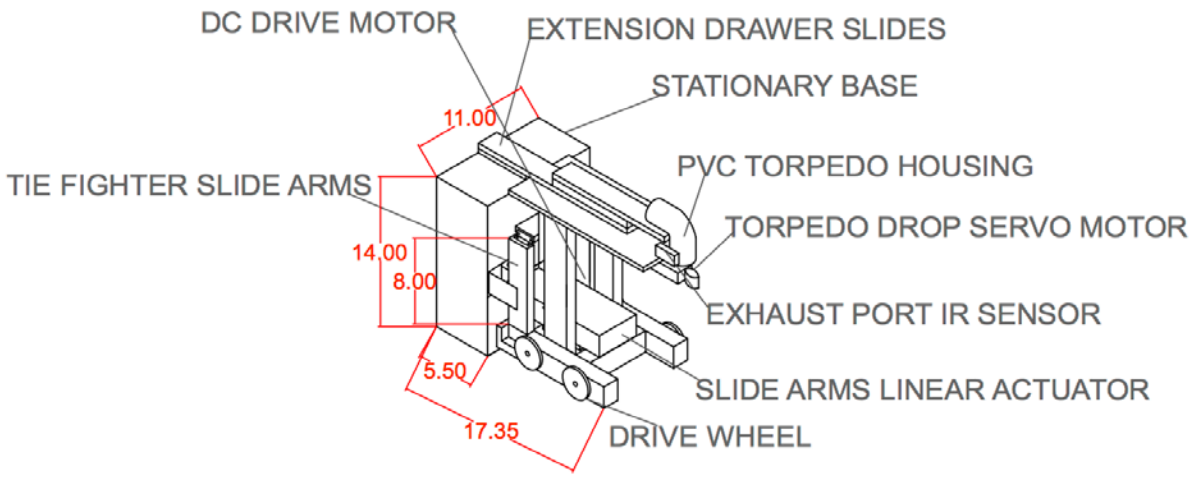

Figure 1: The Glyder

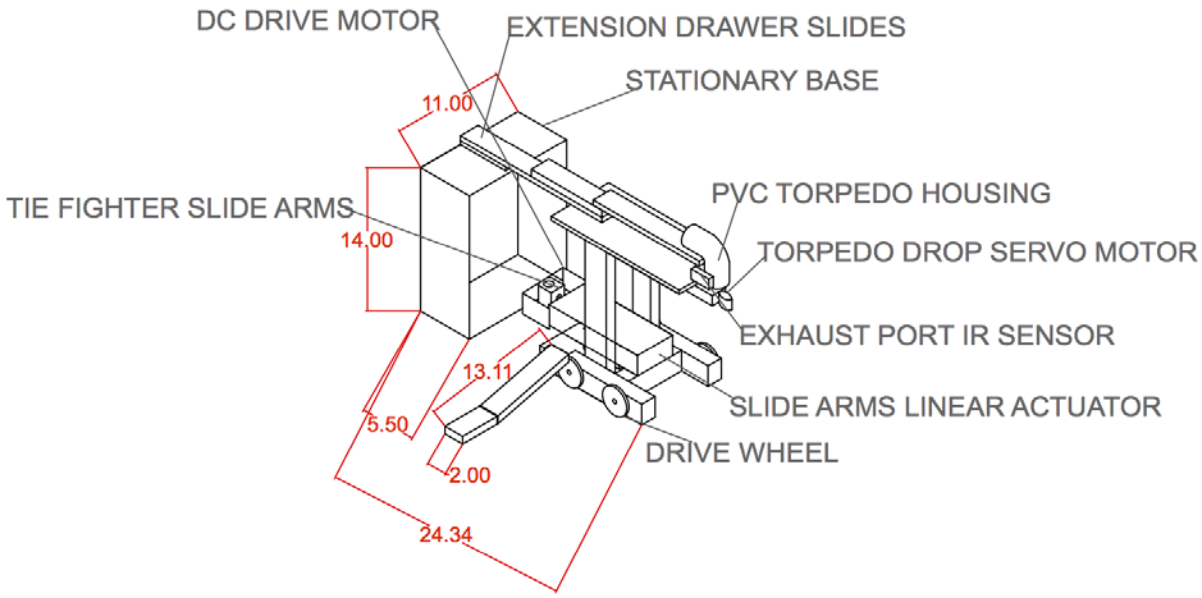

Figure 2: The Glyder Extender

Table 1: House of Quality

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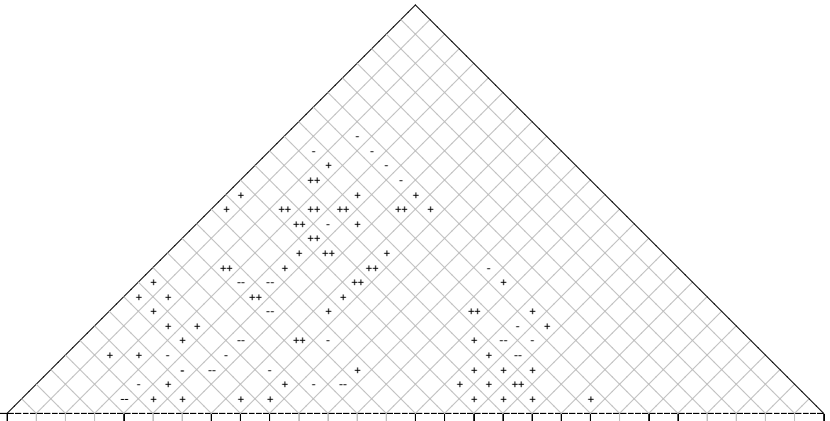
Star Wars

11/17/2017

Legend		
◉	Strong Relationship	9
◎	Medium Relationship	7
△	Weak Relationship	1
▲	Maximize	
▼	Minimize	
x	Target	
++	Strong Positive	
+	Strong Positive	
-	Negative	
--	Strong Negative	



Importance	Customer Requirements \ Engineering Characteristics	Total cost of robot	Height of robot	Number of torpedoes Delivered to Exhaust Port	Number of Droids Recovered	Number of Lightsabers and Force in Jedi Training Zone	Escape time	Number of steps to assemble	Points Removed from Opponents	Length of robot	Width of robot	Operating Time	Number of Torpedoes in the Death Star Zone	Number of steps to reassemble	Distance from starting zone to the Force	Number of mechanical parts	Number of electronic parts	What place does the robot place in competition	Number of Tie Fighters deposited into enemy zones	Maximum Number of Points Gained	Reassemble time	Assemble time	Time it takes to clean up robot	Extension and Retraction Speed
	Direction of Improvement	▲	▼	X	▼	▲	X	▼	▲	▲	▲	X	X	▼	▼	▲	▲	▲	▲	▲	▲	▼	▼	▲
9	Fit into the measurement box		◉							◉	◉		△					△				◎		
6	Save Droids				▣	◉				△		▣				◉	◉	▣		◉			△	
6	Destroy TIE Fighters				◉	△			▣	△		▣	△			◉	◉	▣	◉	◉			△	
8	Destroy the Death Star			◉						△		▣				◉	◉	▣		◉			△	
5	Safely escape the Death Star explosion		△		◉		◉			▣		▣				◉	◉	▣	△	◉			△	◉
6	Recover Force Units into Jedi Training Zone				◉	◉				▣		▣				◉	◉	▣		◉			△	
5	Recover Lightsaber into Jedi Training Zone				◉	◉				▣		▣				◉	◉	▣		◉			△	
3	Put Tie Fighters into another dimension				▣				◉	▣	▣	▣	△			◉	◉	▣	◉				△	
9	Operate Autonomously		△	◉		△	△					◉					◉	▣			◉	▣		
9	Cost less than $100	◉																△						
5	Star Wars themed aesthetics	▣																△						
9	Cannot harm the galaxy												△					▣						
5	Perform better than other robots	▣		▣	▣	◉	◉		◉			▣	▣		◉	◉	◉	◉	◉	◉				
3	Manuever through objects within the galaxy						▣			▣	▣	▣	▣					▣						
9	Must not exceed a run time of 30 seconds			▣	▣	◉	◉					◉			△			▣						◉
9	Must fit completely into the starting zone		◉							▣	▣					△		△						
9	No object from device can exit the outer perimeter								▣	▣	▣		◉					△						
9	Robot must start by the plug-in activation											◉					▣	△			◉			
9	Robot can not become permantly bounded to track			△					▣									△						
9	Robot must be deemed safe for competition			△									◉					△						
4	Weighs less than 15 lbs		◉							◉	◉					◉	▣							
10	Electric components powered off before activation																							
10	Set up time of 3 min and 45 sec or less		△					◉		△	△			◉										
10	Length less than 24 inches									◉														
10	Width less than 12 inches										◉													
10	Height less than 18 inches		◉																					
	Absolute importance	111	230	213	267	294	198	510	171	221	153	384	213	429	54	411	504	317	131	369	162	126	38	126
	Relative Importance	0.02	0.04	0.04	0.04	0.05	0.03	0.09	0.03	0.04	0.03	0.06	0.04	0.07	0.01	0.07	0.08	0.05	0.02	0.06	0.03	0.02	0.01	0.02

185	90	90							
0.03	0.02	0.02							

Good

Table 2: Specification Sheet

		Specification for:	Issued:	10/27/2017
		Final Project: Star Wars	Page 1 of 1	
Changes	D/W	Requirements	Responsibility	Source
		Learn to use the force, learn to use a lightsaber, save droids, destroy TIE fighters, destroy the Death Star, safely escape the Death Star explosion		
		Geometry		
	D	Less than or equal to 18" in height	Team 10	Contest Rules
	D	Length less than or equal to 2'	Team 10	Contest Rules
	D	Width less than or equal to 1'	Team 10	Contest Rules
12/1/2017	W	17" in height	Team 10	Team 10
12/1/2017	W	Length 22" or less	Team 10	Team 10
12/1/2017	W	Width 10" or less	Team 10	Team 10
	W	Robot collects lightsaber 1" forward and places in Jedi Training Zone	Team 10	Contest Rules
	W	Deliver three proton torpedoes minimum 28" from edge of start zone and 12" above the track to get to exhaust port	Team 10	Contest Rules
	W	Robot removes TIE fighters 7" away from start zone	Team 10	Contest Rules
		Kinematics		
12/1/2017	D	Translates 1 m/s to complete tasks	Team 10	Contest Rules
		Forces		
12/1/2017	D	Weight less than 15 lbs	Team 10	Contest Rules
12/1/2017	W	Weight less than 10 lbs	Team 10	Team 10
		Energy		
12/2/2017	D	12 V Power Source	Team 10	Contest Rules
		Materials		
	D	3 Pyboard kits	Team 10	Contest Rules
	D	One Pyboard microcontroller	Team 10	Contest Rules
12/2/2017	D	3 Fasteners	Team 10	Team 10
12/2/2017	W	5 Fasteners	Team 10	Team 10
11/15/2017	D	Less than or equal to 3 Servomotors	Team 10	Contest Rules
11/15/2017	D	1 Linear Actuator	Team 10	Contest Rules
11/15/2017	D	1 IR Sensor	Team 10	Contest Rules
11/15/2017	D	1 Stepper motor	Team 10	Contest Rules
11/15/2017	D	1 5V DC motor ?	Team 10	Contest Rules
11/15/2017	D	1 12 V DC motor	Team 10	Contest Rules
		Tasks		
	W	Collect and place 5 force units completely into the team's Jedi Training Zone	Team 10	Contest Rules
	W	Collect and place 1 lightsaber completely into the team's Jedi Training Zone	Team 10	Contest Rules
	W	Collect and place 2 droids completely into the team's zone	Team 10	Contest Rules
	W	Remove two TIE fighters completely from the team's zone	Team 10	Contest Rules
	W	Deliver 3 proton torpedoes completely into the rotating exhaust port	Team 10	Contest Rules
		Safety		
12/2/2017	D	Can not leave 3' perimeter around track	Team 10	Contest Rules
		Assembly		
11/15/2017	W	Takes less than 30 seconds to assemble on track	Team 10	Team 10
11/15/2017	D	Takes less than 1 minute to assemble on track	Team 10	Team 10
11/15/2017	D	Takes less than 2 minute to box on track	Team 10	Team 10
11/15/2017	W	Takes less than 1 minute to box on track	Team 10	Team 10
		Quality Control		
	D	Able to withstand 20 test runs	Team 10	Team 10
	W	Able to withstand 40 test runs	Team 10	Team 10
		Transport		
12/1/2017	D	Transported with <5 parts	Team 10	Team 10
12/1/2017	W	Transported with <2 parts	Team 10	Team 10
		Operation		
	D	Operate autonomously for 30 seconds	Team 10	Contest Rules
	D	Shut off after 30 seconds	Team 10	Contest Rules
11/15/2017	W	Operate for 28 seconds	Team 10	Team 10
11/15/2017	W	Shut off after 28 seconds	Team 10	Team 10
		Maintenance		
11/15/2017	W	5 easily replaceable parts	Team 10	Team 10
		Recycling		
	W	100% recyclable	Team 10	Team 10
		Costs		
	D	Materials used<$100 excluding aesthetics and fasteners	Team 10	Contest Rules
		Schedules		
	D	Robot setup, operation, and cleanup< 7 minutes	Team 10	Contest Rules
11/15/2017	D	Robot setup< 3 minutes 45 seconds	Team 10	Contest Rules

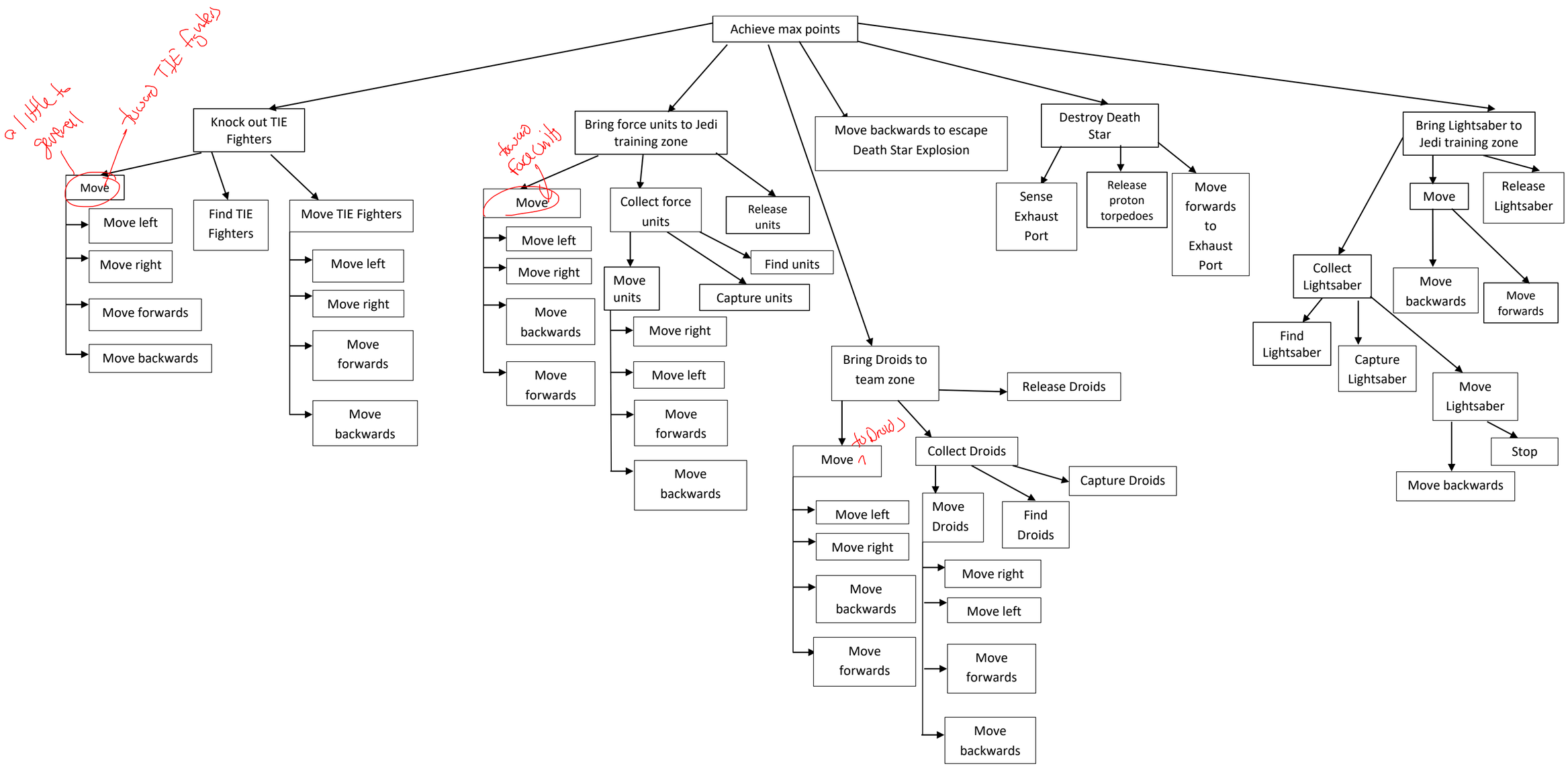


Figure 3: Function Tree

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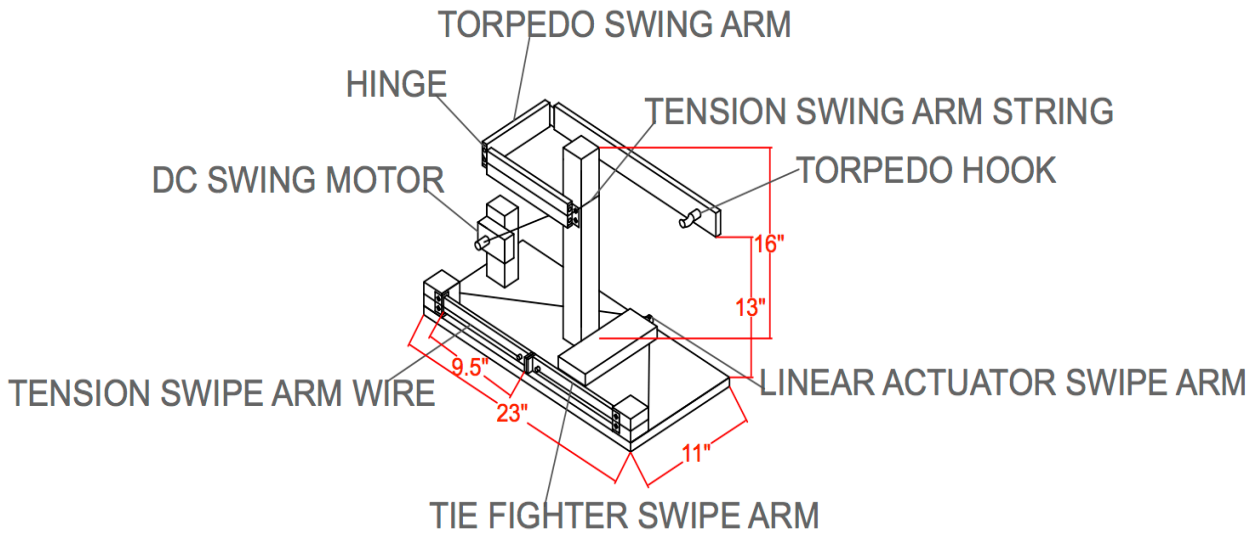


Figure 4: The Swing Man

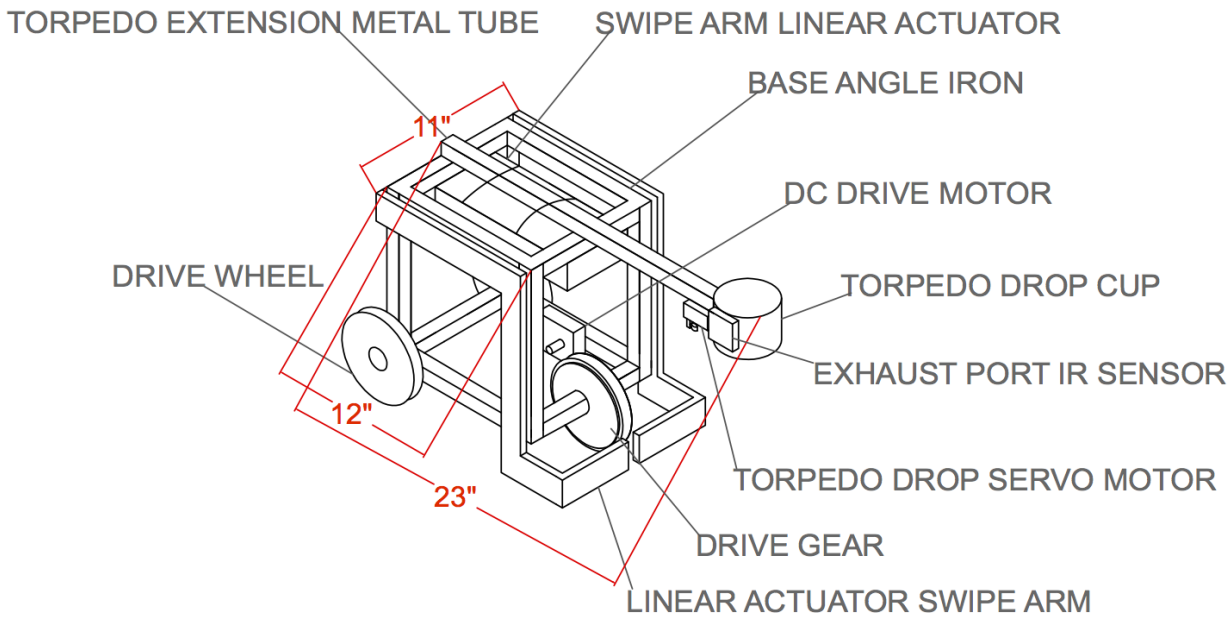
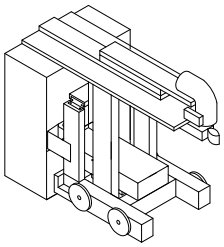
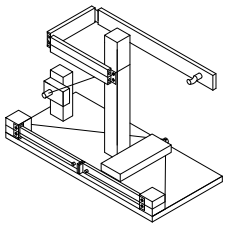
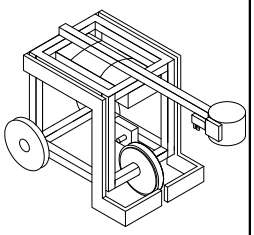


Figure 5: The Tricycle

Table 3: 3rd Level Evaluation Matrix

Importanace	Customer Requirements			
8	Save Droids	3	0	3
6	Destroy TIE Fighters	8	6	7
7	Destroy the Death Star	10	6	9
8	Recover Force units into Jedi Training Zone	5	0	5
9	Recover Lightsaber into Jedi Training Zone	2	0	2
9	Escape Death Star explosion	10	8	6
10	Cost less than $100	10	10	6
10	Must not exceed a running time of 30 seconds	10	10	10
4	Star Wars themed aesthetics	10	6	7
5	Cannot harm the galaxy	10	10	10
5	Manuever through objects within the galaxy	6	5	6
10	Must fit into measurement box	9	8	10
10	Must start from the plug-in activation	10	10	10
10	Cannot become permanently bounded to track or objects	10	10	10
7	Deemed safe for competition	10	10	10
8	Can only be moved as a rigid body once boxed	10	10	10
10	Operate autonomously	10	10	10
8	Perform better than other robots	7	3	5
10	Length of 2' or less	10	10	10
10	Width of 1' or less	10	10	10
10	Height of 18'' or less	10	10	10
5	Weighs less than 15 lbs	8	9	5
9	Set up time of 3 minutes 45 seconds or less	10	8	9
	Total	1636	1420	1505
	Relative Total = Total/Number of Criteria	0.71	0.62	0.65

Pts.	Meaning
0	Unsatisfactory
1	Inadequate
3	Tolerable
4	Adequate
5	Satisfactory
6	Good, but drawbacks
7	Good
8	Very Good
9	Exceeds Req.
10	Ideal Solution