Final Project Concept Evaluation

MCHE 201: Introduction to Mechanical Design
Fall 2017

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Abstract

A war has begun. A massive new weapons known as the Death Star threatens to unravel the very fabric of society. In order to fight back, the rebellion relies on autonomous devices that utilize only gravitational and electrical energy. A problem understanding analysis that uses tools such as the House of Quality, Specification, and Function Tree, provides a way of addressing customer requirements with relevant engineering characteristics. Some of the most important customer requirements such as destroying the Death Star and destroying the TIE fighters can be addressed with relevant engineering characteristics such as maximizing the number of automated steps and maximizing the number of electrical power components used. After a proper analysis is performed, many different designs are considered. From the use of Evaluation Matrices, the final design is chosen. The final design takes the form of a compact, two-level rover that travels out and expands in surface area by using a series of deployable arm attachments. One of the deployable arm attachments consists of an arm on the second level that swings out a carriage. The carriage contains an infrared sensor and servo-deployed trap door that consistently drops the proton torpedo payload in the exhaust port of the Death Star. The two-level design allows the device to better utilize its workable surface area by expanding its functionality. On top of these mechanical highlights, the rover relies on concise and efficient programming design to accomplish tasks quickly before other devices. The final design stems from a focused effort to develop mechanical and program design concurrently. With this effort and a rigorous problem understanding analysis led to an impressive first place finish in the contest. Because of the main focus on functionality above aesthetic design, the device finish only within the top ten in the design review.

Good

1 Introduction

With the galaxy on the brink of war, the need for autonomous devices is greater than ever. These devices carry the brunt of the dwindling Rebel fleet's load. In order to be worth the rebellion's investment, the device will need to learn how to use a Lightsaber, destroy the TIE fighters, learn how to use the Force, save the droids, destroy the Death Star, and finally, escape the Death Star explosion. Each competing device has to accomplish these tasks on the Star Wars Galaxy as seen in Figure 1 [1]. Intelligence obtained by a mole constructing the Death Star suggests that the exact placement varies slightly, but overall, it stays relatively constant. From this intelligence, each device must be inherently robust in design. In order to destroy the Death Star, the device must deliver proton torpedoes to the center concentric circles. For additional points, the device must deliver the proton torpedoes to the center spinning exhaust port. The task presents an interesting engineering challenge because it requires the device to move from the start zone, which is possible through many different mechanisms. The Force units are located right in front of the Death Star. These must be collected back into the Jedi Training Zone. In order to achieve this task, the device must not only move out to reach the Force units, but contain a collection and drop-off mechanism. Directly ahead of the Jedi Training Zone are a pair of TIE fighters and a Lightsaber. The Lightsaber, like the Force units must be collected into the Jedi Training Zone. For additional points ~~and complexity~~, the Lightsaber can be delivered upright. This requires a collection and drop-off mechanism separate from the Force unit collection and drop-off mechanism. Also on the competition area are four droids located on the edge of the team zone. To save them, they must be collected and end up in in the team zone. This task requires not only movement, but collection arms long enough to reach the droids. Finally, each device must return back to the start zone in order to escape the Death Star's explosion. This task introduces the need for a retraction mechanism on top of a deployment mechanism. Table 1 shows the scoring system related to each task. With all of these engineering challenges to juggle, there is also limitations places on device width, length, and height. This limitation complicates an already complex project. On top of all these engineering challenges, includes a requirement that each device must be completely autonomous. This presents the need for an efficient and powerful program design to control every movement of the device.

- a little out of place here

Save solutions for later

With this daunting task ahead, the device will need to have a proper understanding of the problems plaguing its success. To gain this proper understanding, design tools such as the House of Quality, the Specification Sheet, and the Function Tree are used. The design process yields a two-level rover design as the optimum choice for satisfying all customer requirements and engineering challenges. Section 1 details and discusses the final design chosen to address the customer requirements and the engineering challenges associated with the project while Section 2 discusses the problem understanding analysis used to formulate the final design. Section 3 details the concept evaluation used to obtain multiple design alternatives and the ranking system used to evaluate the effectiveness of each device. The section after discusses the performance of the device in the final competition. This includes a discussion on the design review presentation. Section 5 concludes the report by summarizing the findings of the reports. The references are cited in the last section and finally, the figures and tables referenced in the report are attached in the back of the report.

fix section #'s

2 Final Design

The final design chosen consists of a two-level compact rover design that expands and then retracts in surface area depending on the task. The fully expanded rover design can be seen in Figure 2. The device is divided into two levels of operation in order to maximize functionality within the allowable volume. The division also allows for a greater amount of independently moving parts. ~~From the problem understanding analysis, the design decision is found to be necessary to satisfy all major customer requirements~~. The design also allows for a greater reach when attacking the exhaust port, which requires a combination of height and length in order to reach and accomplish the tasks. The rover design allows for greater mobility when trying to save the droids and escape the Death Star explosion. The device utilizes a series of motors to not only achieve movement, but to expand its volume through arm and gear attachments. This gives the device a quickness of deployment that, in turn, helps achieve some of the contested tasks before other devices.

The device is divided into two separate levels of operation. The lower level of the device is where the drive wheel motor, sweeper servos, microcontrollers, motor drivers, and power adapters are located. The drive-wheel motor sets the device in motion through the use of a series of gears. This drive-wheel gear setup can be seen in Figure 3 with a dimension view in Figure 4. The drive-wheel motor spins a gear located on the back drive-shaft of the device. The drive-shaft contains a pair of three-and-a-half inch wheels. This may slow the device down significantly, but its compact design allows for greater freedom of designing other mechanisms that are more critical to overall functionality. ~~The device does not derive quickness from its mechanical design, but from its programming design, which is discussed later~~. The lower level also contains two servo-deployed sweeper arms that extend outward from a storage position that is flush with the sides of the device. This can be seen expanded in Figure 2 and retracted in Figure 5. The decision to utilize servo motors to extend the sweeper arms instead of a gear motor stems from the greater precision and control needed to destroy the TIE fighters. This mechanism provides a defense from the back that will destroy the TIE fighters when the device reverses direction. These servo-sweepers are placed in between the back and front wheels. The center of the lower-level houses the microcontroller and the motor drivers. The strategic placement of the controllers and power adapter allows for a central placement from where the wires can be distributed. This increases the organization of the device while also protecting these components from outside interference and attack, such as TIE fighter attacks or rogue Rebel spacecraft.

Why the change in tone when moving to the upper level?

Judging the effectiveness of the lower-level of the device in relation to the contest rules, the device succeeds in escaping the Death Star explosion and destroying the TIE fighters. This is a modest effort that yields net positive points, but it is simply not good enough. In order to attain more points consistently, the device needs more functionality than just moving forward and back while deploying sweeper arms. With this current lower-level design, there are four critical customer requirements that go unaddressed. With space becoming an issue with the lower-level due to the size restraints, there is nowhere to go but up.

awkward

I don't think this paragraph really adds anything to the report.

The final design utilizes a second, upper-level that ~~builds on top of the first. Each device is limited in its length, width, and height. The limitation presents an interesting design and engineering challenge. The device must be not only compact, but dense in functionality. The~~

~~addition of the second level allows for the inclusion of more moving parts that will maximize the score for each run of the device. The upper level~~ will allow the Rebels to accurately and consistently destroy the Death Star, save the droids, and learn how to use the Force. The device does this through the use of motors to extend arms from the main device and reach its goal. The wide sweeper arms that expand from the back are used to save the droids and learn how to use the Force. Since the Rebel's main objective is to rid the galaxy of the evil Empire by destroying the Death Star, the device will need to stay on course. This means that the device will need a wide reach to save the droids from the Empire. A lightweight yet strong material will be added to the arms in order to maximize the surface area to save the droids. This mechanism can be seen in Figure 2. This mechanism provides the device robust functionality and allows the device to save the droids regardless of where the Empire is imprisoning them. When the device retracts the droids safely into the pod bay doors, the device will, as a result, also learn how to use the Force. It does this by gathering a curious collection of Force units, also known as midichlorians, located near the Death Star. The placement of these midichlorians can only be explained by the guiding hand of Obi-Wan Kenobi. The collection of the Force units guides the device into destroying the Death Star. The device destroys the Death Star by an extended arm that launches three proton torpedoes into the accuracy of the exhaust port. The accuracy of the proton torpedoes stems from the use of an infrared sensor that detects when the spinning exhaust port is in the line of sight of the drop arm. The proton torpedoes are housed safely and deployed by a servo that drops the floor out from under them. The arm that contains this infrared sensor and proton torpedoes is deployed through the use of a DC motor. The DC motor swings the proton torpedo arm directly over the Death Star, then starts to sense the exhaust port. The proton torpedo delivery mechanism can be seen in Figure 6. Overall, the second level of the device is which sets the final design apart from the others. The first level sets the stage for what the second level accomplishes. Without a well-thought out and executed first level, the second stage accomplishes nothing.

A good mechanical design is not enough when designing these devices. One of the main customer requirements is the need for these devices to operate autonomously. Otherwise, they cannot be put to use against the Empire. In order to address this customer requirement, the final design utilizes a microcontroller and a series of motor drivers. The microcontroller and motor drivers command the device in its operation. It controls the process with which the device accomplishes each task. This process is often neglected in mechanical design, but is truly integral to the overall success of the device. This is a major part of the final design because without it, the device is just one big space paperweight. One of the most important aspects of the programming design is the infrared proton torpedo launcher. As discussed before, a DC motor swings out the proton torpedo arm. Once this is deployed, the infrared sensor stars to read the distance between the arm and the Death Star. If the device reads a distance that is less than twelve centimeters, then the device will not deploy the proton torpedoes as the exhaust port is not passing. If the sensor reads a distance greater than twelve centimeters, then it will drop the proton torpedoes. The most important aspect of this mechanism is its failsafe. In space, anything can happen and because of this, if for some reason the device misaligns with the exhaust port, it will drop anyway only after a predetermined time period and begin its escape from the explosion. This design decision could save at least a minus twenty point penalty because of the devices inability to escape the explosion. This mechanism prevents the device from getting stuck within a loop.

3 Problem Understanding

In order to wage a successful war against the Empire, a knowledgeable understanding of the problems involved with the design is necessary. In order to assist with this process, the House of Quality, Specification Sheet, and Function Tree provide a procedure of thinking about the design that obligates overall understanding if properly utilized. The House of Quality consists of the Problem Understanding Form, which shows the relationship between customer requirements and engineering characteristics, and the Correlation Matrix, which shows the relationship between one engineering characteristic and another. The Specification Sheet takes a number of different engineering characteristics and assigns a realistic goal to it. The specifications are divided into demands or wants. Finally, the function tree outlines a wide number of different functions and breaks them down into different sub-functions.

Save this intro for each tool

The House of Quality acts as a tool to analyze the problems plaguing the designing and manufacturing of the device. The Problem Understanding Form in Table 2 shows the most important engineering characteristic~~s~~ is the total time of operation. Since the majority of the points can be contested by the other team, the speed with which this devices achieves each task is of great importance. For example, the entrance to the exhaust port can be blocked by the other team. If this happens before the device gets to the exhaust port itself, then those points are no longer attainable. This could easily lead to the downfall of the device. So, the speed of accomplishing these tasks is a major specification to consider with the device. With this also comes the consistency with which the device achieves these tasks. The device cannot disregard the structural integrity of the device at the expense of speed. The device can only withstand so much stress before failure. If the device loses its calibration because of the forces incurred after each run, then it is an inherently inconsistent device. For this reason, the Correlation Matrix in Table 3 is used. The Correlation Matrix gives insight into how maximizing or minimizing a certain engineering characteristic affects another. For example, if the total cost of the device is sought to be minimized, this is made harder by the goal of maximizing the number of automated steps. If the device have more functions, it will inherently cost more. From the complete House of Quality analysis, the top engineering characteristics are the number of automated steps, the average point total, the number of electrical power components used, the number of sensors used, and the total number of tasks fully achieved. This is found using the Absolute and Relative Importance Chart in Table 4. Because this analysis is conducted, this valuable information leads to an overall better final design.

good

good

good

shown in Table 5

The Specification Sheet helps organize and set numerical goals for many different engineering characteristics. ~~Table 5 shows the Specification Sheet. The origin for each specification is stated.~~ The origins range from explicit customer requirement specifications from the end user to implicit design team specifications. The Specification Sheet especially is a living document. This is updated as knowledge of the project expands. For example, the overall speed of the device was not known initially, so a somewhat arbitrary goal is stated. As understanding of the problems and the solutions arise, the Specification Sheet is updated. As the table shows, the specifications are divided into different categories. For example, the wish of having a Death Star arm extension length of seven inches falls under the Geometry label, while the wish of having an overall weight

Avoid chronological, narrative construction less than twenty-five pounds falls under the Forces label. As can also be seen from the table, the specifications are divided into either a wish or a demand. A demand takes precedence over a wish as the origin of more demands come directly from the end-user. If the specifications the end-user wants are not met, then the device does not solve their problem. For example, the specification of having a setup time less than three minutes and forty-five seconds, while the design team demands that the setup time be less than two minutes to allow for troubleshooting if problems arise. ~~All of these specifications are considered whenever designing the final device~~.

The Function Tree breaks down what each device should be able to do, regardless of design, in order to satisfy the customer requirements. It does so by organizing broad, overall primary functions and breaking them down into relevant sub-functions, called secondary functions. These secondary functions can again be broken down into more sub-functions, these being tertiary functions. ~~Table 6, shows the~~ Function Tree. On the Function Tree, one of the main primary functions is to operate autonomously. It has a secondary function of being able to communicate between the microcontroller and the electrical power components, which in turn has a tertiary function of being able to move an arm. The lowest level sub-functions become what is outlined in the Prioritization Matrix later discussed within the report. The lowest level sub-functions also serve as a stepping stone for achieving the overall function of the device. Dividing the functions in this manner provides valuable insight relevant to the design process.

shown in Table 6,

4 Concept Evaluation

Three different designs ~~are~~ considered for the final design. These include the final, two-level rover design, a stationary extender design, pictured in Figure 7 and 8, and a rover-extender hybrid, pictured in Figure 9 and 10. The stationary extender design consists of a pulley system that releases arms from an upright position that would destroy the TIE fighters and save the droids. Once collected, the same pulley system brings them back into the device. In order to destroy the Death Star, a rail system extends out and deploys a box carrying the proton torpedoes to the Death Star. Once deployed, a DC motor retracts the arms using another, separate pulley system. The extender-rover hybrid utilizes this same system, but uses a rover to accomplish the other tasks. Because of the height needed to reach the Death Star, a small, compact rover is placed underneath the rail system and is deployed separately from the main device. This rover saves the droids, collects the force units, and destroys the TIE fighters before final returning back, escaping the Death Star's explosion.

Reference the figures as you discuss the designs, rather than in bulk like this.

need a bit more explanation of alt. designs

With three possible designs to consider, there needs to be a way of evaluating and ranking each design in its overall effectiveness in accomplishing many different tasks. That aspect is where the Evaluation Matrices come into play. In utilizing a Third-Level Evaluation Matrix, the three design concepts can be graded on their effectiveness at accomplishing the tasks of the project. For example, in the completed Third-Level Evaluation Matrix in Table 7, the three design alternatives are graded in their ease of transportation. The final design scored the highest while the extender and the extender/rover hybrid failed to live up to the final design in this respect. In utilizing the Third-Level Evaluation Matrix, key distinctions must be drawn in order to fully and effectively consider a final device. The final design's ability to outperform other design alternatives overall is what led to it being chosen for the final design. Apart from this customer requirement, the final design outperforms the design alternatives in its ability to learn to Use the

Be more concise here.

Force, Destroying the Death Star, saving the droids, and learning how to use a Lightsaber. The final design accomplishes these tasks with quickness and consistency. The Final Design also utilizes more electromechanical components, whether it be servos, DC motors, the linear actuator, or a stepper motor, than the other devices. While this increases the complexity of the overall device, it also addresses tasks separately instead of as a collective, with increases the effectiveness and functionality of the device. The final design also more quickly achieves the tasks and returned back to the start zone. The stationary design only slightly outperformed the two-level rover design in regard of destroying the Death Star. Because of these reasons, the final design is chosen.

ok

5 Design Performance Evaluation

The two-level rover device is designed with consistency in mind. Because of this design choice, the device was able to not only make it to the finals, but win in a hard-fought match. The two-level rover excelled in its ability to consistently score over thirty points, with a max run of seventy-five points. This consistency led to it accumulating three first place finishes and two second place finishes. The design is focused on destroying the TIE fighters, destroying the Death Star, and escaping the Death Star's explosion. The device was able to deliver the proton torpedoes to the death star all five rounds, with them landing in the exhaust port three of those times. This was due to the built-in failsafe within the proton torpedo carriage. This truly was the main strength of the device's design. Less focus would have been placed on this aspect of the device's functionality if not for the problem understanding analysis revealing the true importance of the task. Because of a complication where the device got stuck on another device's arms, the device failed to escape the Death Star's explosion only once. In regards of the programming design, the device correctly assumed the path most other devices would take. Most of the competing devices would travel forward, extend arms, and then travel back before finally traveling to the center Death Star. The two-level rover traveled directly to the Death Star. This was made possible by the servo-deploy TIE fighter destroying arms. Because of the compact design of these arms, they could be deployed after the device already reached the Death Star and destroy the TIE fighters as it returned to the start zone. The device was also rigorously tested and calibrated to ensure the robust design. The device competed on two different tracks and in many different zones. The calibration and testing allowed the device to excel on any track and any start zone.

relate back to the design process

While the device was also designed to save the droids, to learn how to use the Force, and to learn to use the Lightsaber, this was not the main focus. Because of this, there was some inconsistency in accomplishing these tasks. Even with this inconsistency considered, there was not a round where the device did not at least collect and droid or Force Unit. Because of this inconsistency, scoring ranged from a minimum of thirty-five points to a maximum of seventy-five points. The seventy-five point run is an outlier as this is not the device's usual performance. In the semifinal match, the device ran as expected up until the collection of the force units and the saving of the droids. Directly to the left of the device was a design with equally long arms tasked to collect and save the droids. The retraction of the arms led to both devices getting stuck out in the team zone and failed to return back to the start zone. Considering this event, there are multiple failsafe to consider to ensure this event no longer occurs. These could range from more rigid arms, smaller arms, or a higher torque driveshaft to ensure the device escape the Death Star's explosion. This event led to a tie-breaker situation which to led the two-level rover only just beating out the competition. Even with this slight performance inconsistency, the device scored consistently enough to stay out of the loser bracket.

In the design review presentations prior to the final contest, the device is scored in the ingenuity of the design, the aesthetics of the design, and the presentation of the design. The two-level rover scored an 8.33 in both the ingenuity of the design along with the presentation of the design. This lands the device in the top five in both of these categories. The device lacks significantly when it comes to the aesthetics of the design. The device~~s~~ lands only within the top twenty devices with a 7.17 score in this category. This is due to the devices truly prototype aesthetic and look. The device does not adequately satisfying the visually appealing customer requirement because it is deemed not as important as the functionality of the device. Very little attention is placed on painting, decorating, or organizing an aesthetically pleasing device. This is what resulted in the low score in this category.

very sentence structure same

6 Conclusion

The two-level rover design is the best design suited for accomplishing the majority of the tasks given. The design process is guided by an extensive problem understanding analysis that utilizes the House of Quality, Specification Sheet, and Function Tree. The device excels in destroying the Death Star, destroying the TIE fighters, and escaping the Death Star's explosion. These tasks are prioritized because the problem understanding analysis found these tasks are most important to customer satisfaction. It achieves these tasks through the use of deployable arms that reach out and accomplish its assigned task. The programming design is heavily considered with the design and its mechanical structures. This yields a device that is focused primarily on functionality. The device is only slightly above average in its achievement of saving the droids, learning how to use the Force, and learning how to use the Lightsaber. These tasks are found to be less important to customer satisfaction. Because of this focus primarily on a task-oriented device, the device was able to reach the finals and win the overall competition. Because of its focus on functionality over aesthetics, the device scored eighth in the design review presentations. This could have been improved by a slightly increased attention on aesthetics.

ok

7 References

[1] J. Vaughan, "The MCHE 201 Galaxy Far, Far Away" 2017, http://crawlab.org/classes/MCHE201_Fa17/Projects/MCHE201_FinalProject_Fall2017.pdf

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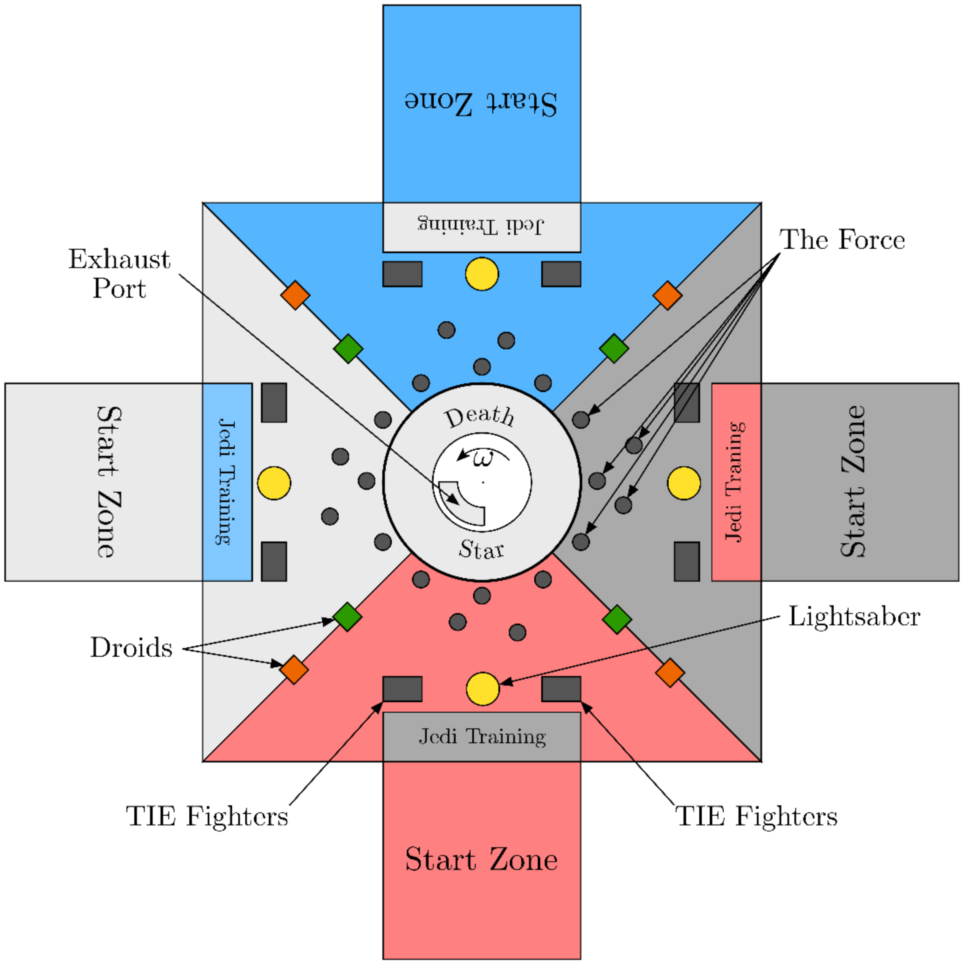

Figure 1: Star Wars Galaxy Track [1]

Table 1: Scoring System for Final Contest

Task	Number of Units	Points per Unit	Maximum Total Points
Learn to Use the Force	5	5	25
Learn to Use a Lightsaber	1	5 or 10	10
Save Droids	4	5	20
Destroy TIE Fighters	2	-10	-20
Destroy the Death Star	3	5 or 10	30
Escape the Death Star Explosion	1	20	20

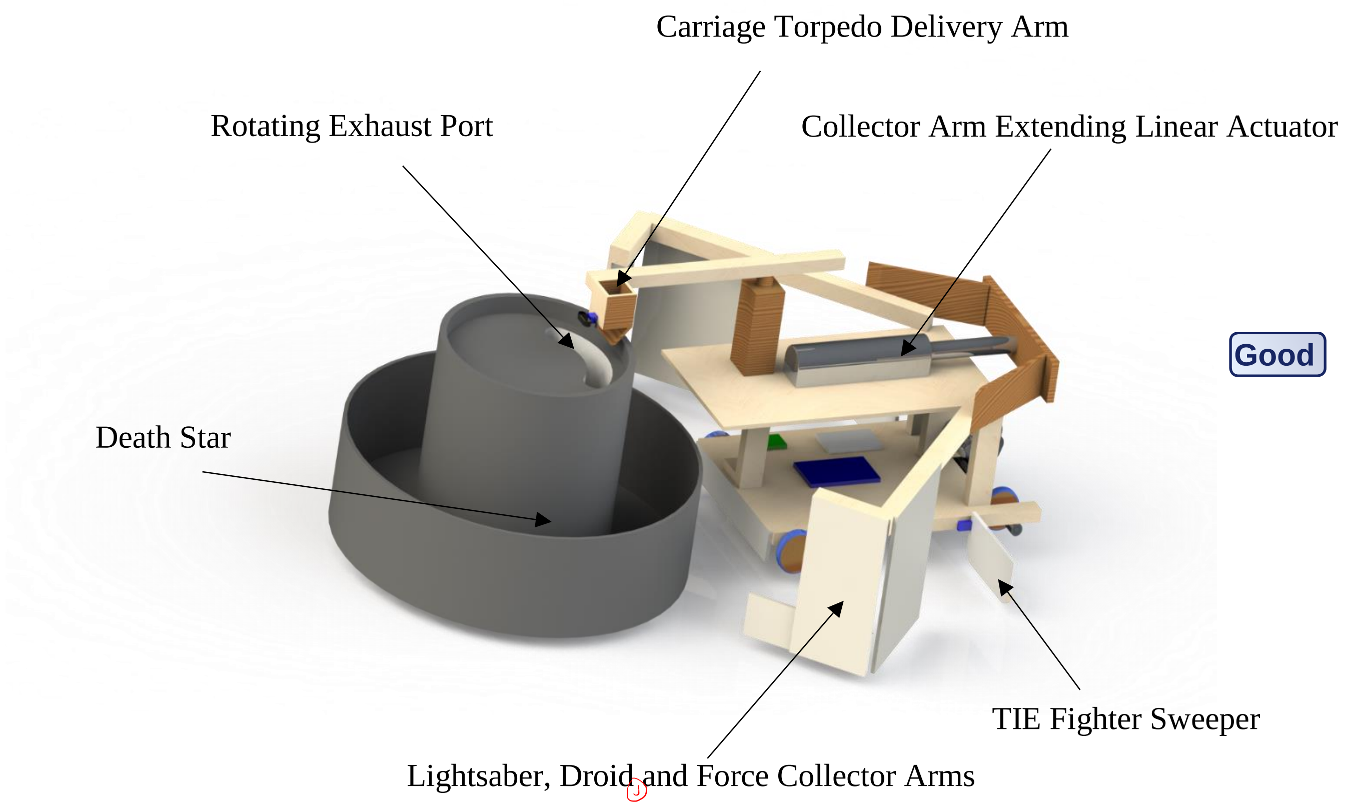

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Figure 2: Expanded View of Two-Level Rover Design

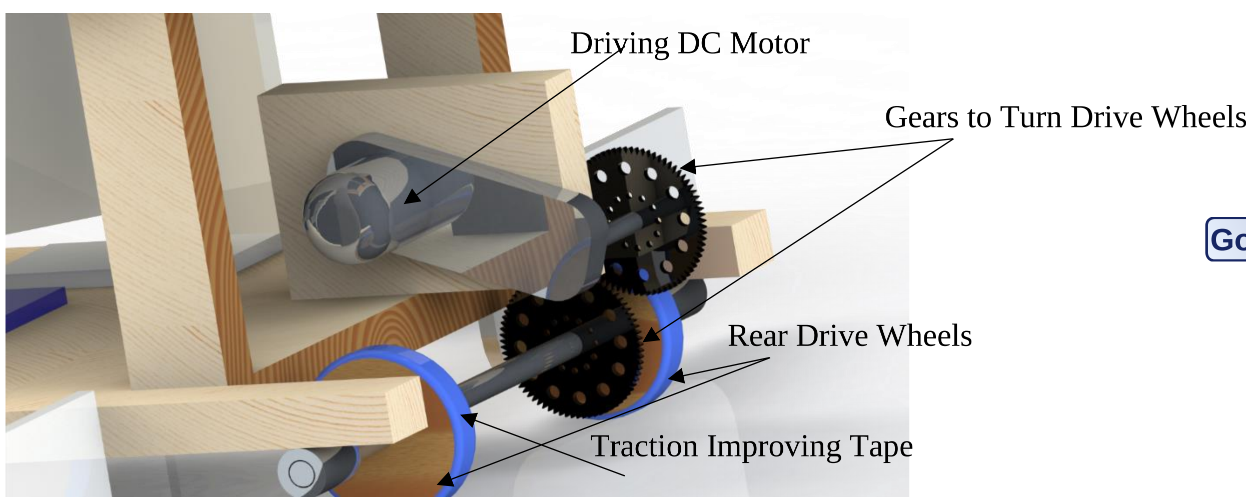

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Figure 3: Drive-Wheel Assembly

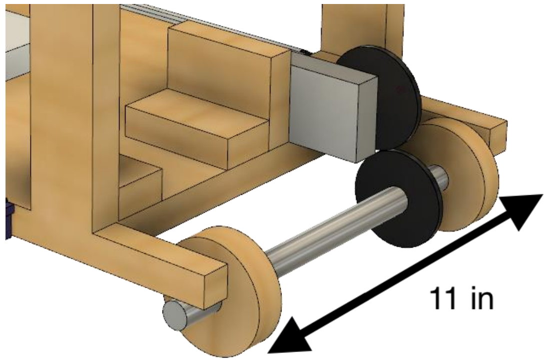

Figure 4: Drive-Wheel Dimension View

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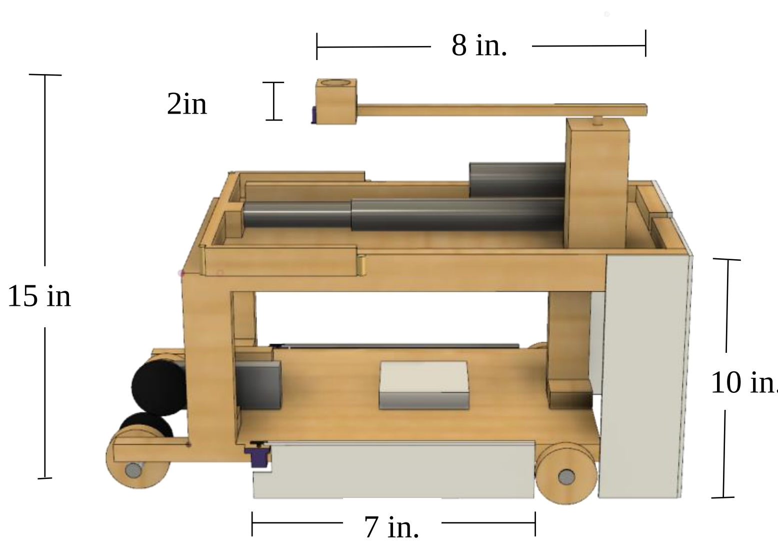

Figure 5: Side View of Two-Level Rover

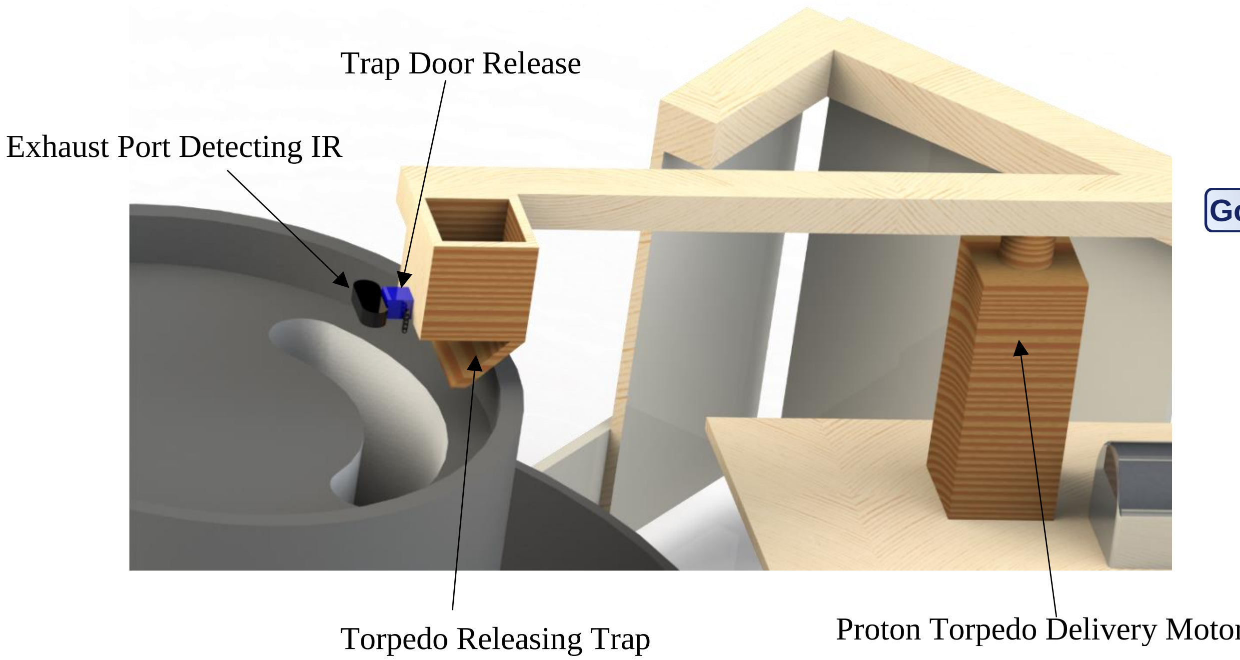

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Figure 6: Proton Torpedo Release Mechanism

Table 2: Problem Understanding Form of the House of Quality

Importance	Customer Requirements \ Engineering Characteristics	Weight of Device	Total Time of Operation	Manufacturing Steps	Manufacturing Time	Setup Steps	Setup Time	Total Tasks Fully Achieved	Length of Longest Side	Length of Shortest Side	Total Height of Device	Clean-up Time	Number of Automated Steps	Total Cost of Device	Average Point Total	Operation Radius	Number of Sensors Utilized	Number of Screw Attachments Used	Time To Destroy Death Star	Time to Save the Droids	Number of Electrical Power Components Used	Number of Detached Parts From Main Device (Post Start)	Number of Points Prevented	Number of Gravity Powered Operations	Total Number of Parts	Time to Destroy the TIE Fighters	Time to Learn How to Use a Lightsaber	Time to Escape the Death Star	Time to Learn How to Use the Force
	Direction of Improvement	▼	▲	▼	▼	▼	▼	▲	▼	▼	▼	▼	▲	▼	▲	▲	▲	▼	▼	▼	▲	▼	▲	▲	▼	▼	▼	▼	▼
8	Autonomous Operation		△		▣	△	▣	△					◉	▣	△	◉	◉		▣	▣	◉		△	◉	▣	▣	▣	▣	▣
6	Easy to Transport	◉							◉	◉	◉						▣	△			▣			▣	◉				
7	Easy to Setup Prior to Contest	◉	△	△	▣	◉	◉					△	▣				◉	△			◉	▣	▣	◉	△				
8	Quick to Setup Prior to Contest	◉			▣	◉	◉	△				△	▣				▣	△			▣	▣	▣	◉	△				
7	Building Material Less Than $100				▣									◉			▣	△			◉			△	◉				
10	Accomplish Task: Learn to Use the Force		▣		▣	△	▣	◉	▣	△	△	△	◉	△	◉	▣	△	△	△	△	◉	▣		▣	◉	△	△	△	◉
10	Accomplish Task: Learn to Use a Lightsaber		▣		▣	△	▣	◉	▣	▣	▣	△	◉	△	◉	△	▣	△	△	△	◉	△		▣	◉	△	◉	△	△
10	Accomplish Task: Destroy the Death Star		▣		▣	△	▣	◉	▣	▣	▣	△	◉	△	◉	◉	▣	△	◉	△	◉	△		◉	◉	△	△	△	△
10	Accomplish Task: Save the Droids		▣		▣	△	▣	◉	△	▣	△	△	◉	△	◉	◉	▣	△	△	◉	◉	△	◉	◉	◉	△	△	△	△
10	Accomplish Task: Safely Escape the Death Star Explosion		▣		▣	△	▣	◉	▣	▣	▣	△	◉	△	◉	△	◉	△	◉	△	◉	△		▣	◉	△	△	◉	△
10	Must Fit Within 1ft x 2ft Base Area	△			△				◉	◉	△			△		▣									△				
10	Height Must be Less Than 18 Inches	△			△				△	△	◉			△		△									△				
8	Must Utilize only Gravity or Power From Board		△	△	▣	△	△	◉					◉		◉		◉		▣	▣	◉			◉	▣	▣	▣	▣	▣
9	Operate Fully Within 30 Seconds				△			◉				▣			◉		◉		◉	◉	◉		▣	◉	◉	◉	◉	◉	◉
4	Visually Appealing													△				◉			▣	◉			▣				
5	Easy Manufacturing Assembly			◉	▣	▣	▣		△	△	△	△	◉				◉	◉	△	△	◉	◉	▣	◉	▣	△	△	△	△
6	Pickup Within 2.5 Minutes	▣	△	△	△	△	△	▣				◉	▣			▣						◉			▣				
10	Score Maximum Number of Points per Run		◉		△			◉					▣		◉		△		◉	◉	△	△		△	▣	◉	◉	◉	◉
5	Operates Within 3ft Playing Radius		△		△	△	△		▣	▣	▣	△				◉	△								△				
7	Few Set up Steps	△	△	▣	▣	◉	◉						◉		▣		◉				▣	▣	△	▣	△				
7	Destroy Death Star Before Other Team Blocks Pathway		◉		△			▣				△	▣		◉	△	▣		◉	△	▣	△		△		△	△	△	△
7	Save the Droids Before Other Team		◉		△			▣				△	▣		◉	△	▣		△	◉	▣	△		△		△	△	△	△
6	Does Not Pollute the Playing Area				▣				△	△	△	▣				△						◉			△				
5	Prevents Other Teams from Scoring		◉		▣		△					△					◉		◉	◉			◉	▣					
10	Reliable in its Contest Operation		△	▣	▣	▣	▣	◉				△	▣		◉		▣		▣	▣	▣			▣		▣	▣	▣	▣
10	Robust Design for Varying Playing Area Conditions		△		△	▣	▣								◉		◉				▣		△	▣					
9	East to Reset Device for Consecutive Runs			▣	▣	◉	◉	▣				△	◉			△	▣	△			△			△					
8	Shuts Down Operation after 30 Second Operation Time		◉					◉					◉		◉		▣		◉	◉	▣		▣	▣		◉	◉	◉	◉
10	Begins When Start Button is Pressed		◉										◉				◉		△	△	△			△		△	△	△	△
5	Does Not Damage Playing Area	◉																	△	△		◉				△	△	△	△
5	Does not Cause Wanton Destruction to Other Devices	◉																	△	△		◉				△	△	△	△
7	Autonomous Assisted Setup					◉	◉					◉	◉				◉				▣	△		▣					
10	Accomplish Task: Destroy the TIE Fighters		▣			▣	▣	◉				△	◉	△	◉		△		△	△	▣					◉	△	△	△
5	Easy to Store after Contest	▣							◉	◉	◉							▣			▣	▣		▣	▣				

Symbol	Relationship	Value
◉	Strong	9
▣	Medium	3
△	Weak	1

Symbol	Direction
▲	Maximize
▼	Minimize
x	Target

Why so blurry?

Table 3: Correlation Matrix

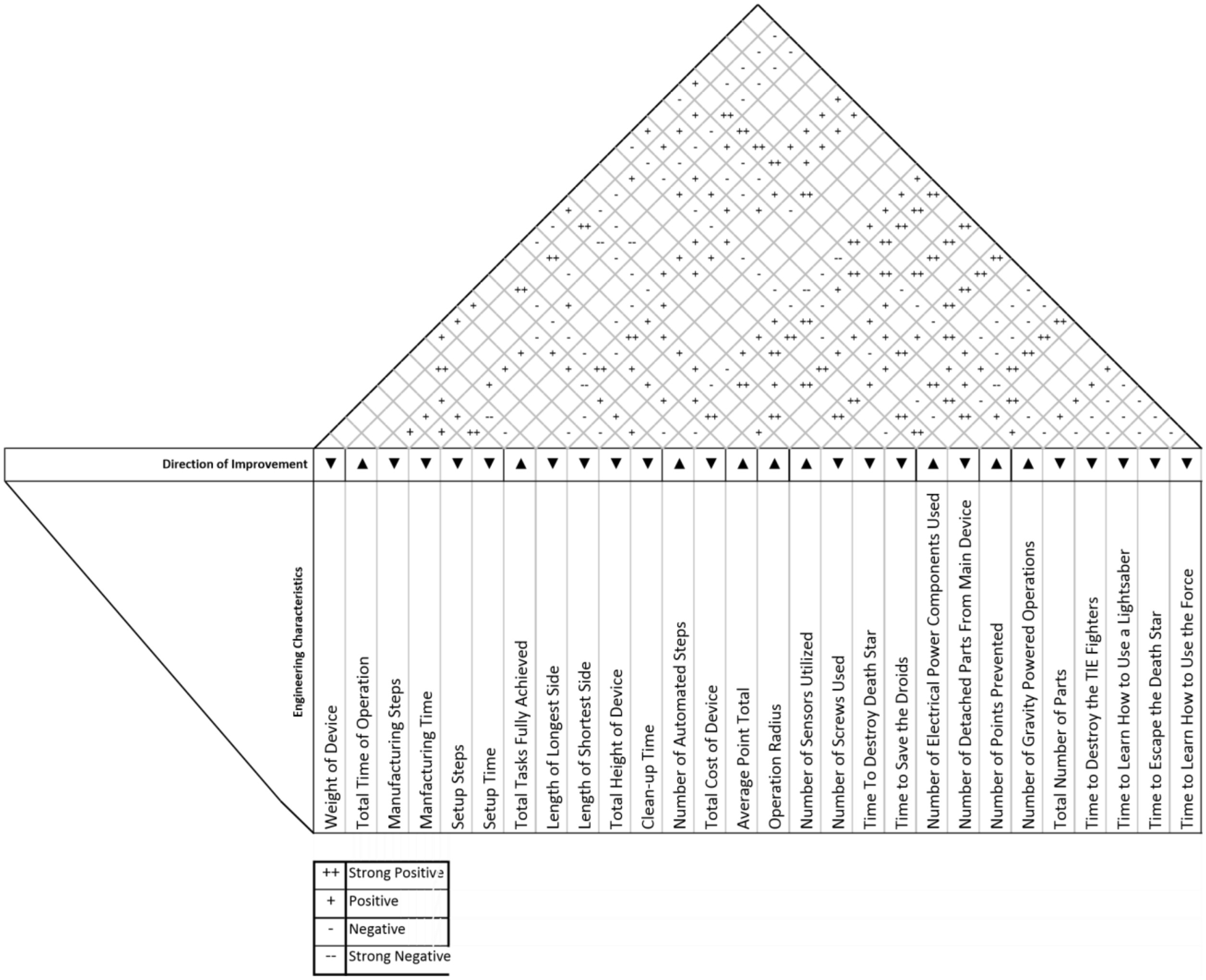

Table 4: Absolute and Relative Importance Chart

Engineering Characteristics	Relative Importance (%)	Absolute Importance
Weight of Device	2.1	339
Total Time of Operation	4.1	664
Manufacturing Steps	0.9	144
Manufacturing Time	2.8	464
Setup Steps	3.2	524
Setup Time	3.9	645
Total Tasks Fully Achieved	6.4	1048
Length of Longest Side	2.2	355
Length of Shortest Side	2.2	355
Total Height of Device	2.0	335
Clean-up Time	1.7	285
Number of Automated Steps	7.7	1263
Total Cost of Device	1.0	171
Average Point Total	7.3	1190
Operation Radius	2.6	434
Number of Sensors Utilized	6.6	1085
Number of Screw Attachments Used	1.1	183
Time to Destroy Death Star	4.2	681
Time to Save the Droids	3.7	601
Number of Electrical Power Components Used	7.0	1142
Number of Detached Parts from Main Device (Post Start)	2.8	461
Number of Points Prevented	1.7	271
Number of Gravity Powered Operations	5.5	899
Total Number of Parts	5.1	839
Time to Destroy the TIE Fighters	3.1	500
Time to Learn How to Use Light Saber	3.1	500
Time to Escape Death Star	3.1	500
Time to Learn to Use the Force	3.1	500

Table 5: Specification Sheet

		Specification for:	Issued:	10/13/2017
Changes	**D/W**	**Requirements**	**Responsibility**	**Source**
		Design a multifunctioning, autonomous robot		
		Geometry		
	D	Length less than 12 inches	Design Team	Contest Rules
	W	Length less than 11 inches	Design Team	Design Team
	D	Height less than 18 inches	Design Team	Contest Rules
	W	Height less than 17 inches	Design Team	Design Team
	D	Width less than 24 inches	Design Team	Contest Rules
	W	Width less than 23 inches	Design Team	Design Team
	D	Death Star Arm reach 6 inches	Design Team	Contest Rules
	W	Death Star Arm reach 7 inches	Design Team	Design Team
	D	Droid Arm Collection Length of 10 inches	Design Team	Design Team
	W	Droid Arm Collection Length of 12 inches.		
		Kinematics		
	W	Top speed of .25 m/s	Design Team	Design Team
	W	Acceleration greater than .09 m/s	Design Team	Design Team
	W	Stops within 1 second of code signal	Design Team	Design Team
	W	Reach Death Star in less than 2 seconds	Design Team	Design Team
	D	Reach Death Star in less than 5 seconds	Design Team	Design Team
	W	Return to the Start Zone with 10 seconds remaining	Design Team	Design Team
	D	Return to the Start Zone with 5 seconds remaining	Design Team	Design Team
		Forces		
	W	Weight less than 25 lb	Design Team	Design Team
	W	Weight of overall device less than 10 lb	Design Team	Design Team

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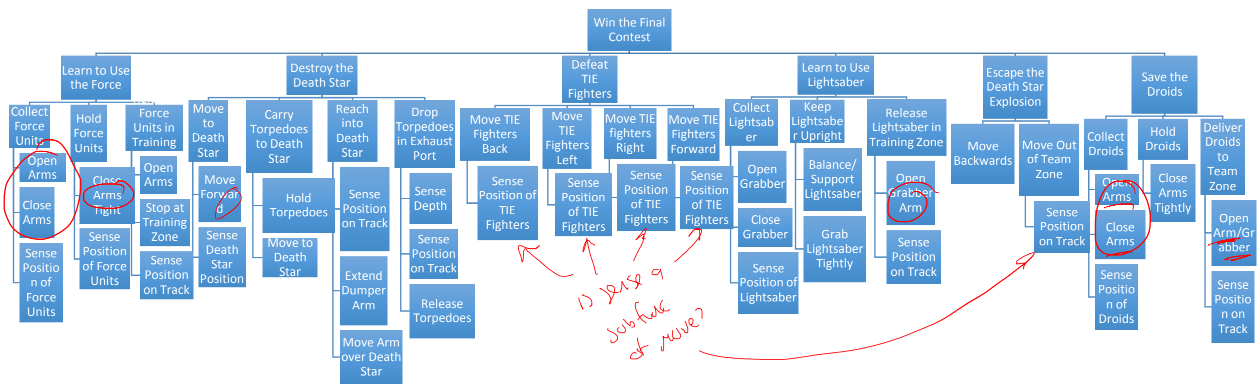
Table 5: Specification Sheet (cont.)

	W	Weight of overall device less than 40 lb	Design Team	Design Team
		Energy		
	W	Power consumption less than 12 V	Design Team	Design Team
	D	Power supply = 12 V	Design Team	Contest Rules
		Materials		
	D	Use of one Pyboard	Design Team	Contest Rules
	D	Use of one or more breadboards	Design Team	Contest Rules
	W	Use of 1 g/cm^3 material	Design Team	Design Team
	D	Cost less than $100	Design Team	Contest Rules
	D	Use of 1 Actuator	Design Team	Contest Rules
	D	Contains no more than 2 DC motors	Design Team	Contest Rules
	D	Contains no more than 1 stepper motor	Design Team	Contest Rules
	D	Contains no more than 3 servo motors	Design Team	Contest Rules
		Signals		
	D	Robot begins within 3 seconds of start signal	Design Team	Contest Rules
	W	Robot begins within 1 second of start signal	Design Team	Design Team
	W	Robot begins at start signal		
		Safety more about this in rules		
	D	Reactivity of zero	Design Team	
		Assembly		
	W	Set up takes less than 2 minutes	Design Team	Design Team
	D	Setup takes less than 4 minutes	Design Team	Contest Rules
	D	Take down less than 2.5 minutes	Design Team	Contest Rules
	W	Take down less than 1 minutes	Design Team	Design Team
	W	Robot takes less than 5 days to build	Design Team	Design Team

Table 5: Specification Sheet (cont)

	W	Assembled in less than 15 steps	Design Team	Design Team
		Transport		
	W	Consists of less than 4 transportation pieces	Design Team	Design Team
		Operation		
	D	Operate autonomously with less that 150 lines of code	Design Team	Contest Rules
	D	Complete tasks in less than 30s	Design Team	Contest Rules
	W	Complete tasks in less than 25s	Design Team	Design Team
	W	Robot takes less than 3 days to program	Design Team	Design Team
	W	Robot contains less than 20 programming functions	Design Team	Design Team
	D	Robot averages more than 30 points scored	Design Team	Contest Rules
	W	Robot averages more than 80 points scored	Design Team	Design Team
	W	Minimum score of 20 points	Design Team	Design Team
		Maintenance		
	D	Boxed and ready to operate in less than 3 minutes	Design Team	Contest Rules
	D	Boxed and ready to operate in less than 3:45 minutes	Design Team	Contest Rules
		Costs		
	D	Extra materials cost less than $100	Design Team	Contest Rules
		Schedules		
	D	Ready for preliminary contest before November 19th	Design Team	Contest Rules
	D	Ready for qualifier before November 2nd	Design Team	Contest Rules
	D	Ready for final contest before November 11th	Design Team	Contest Rules

Table 6: Function Tree



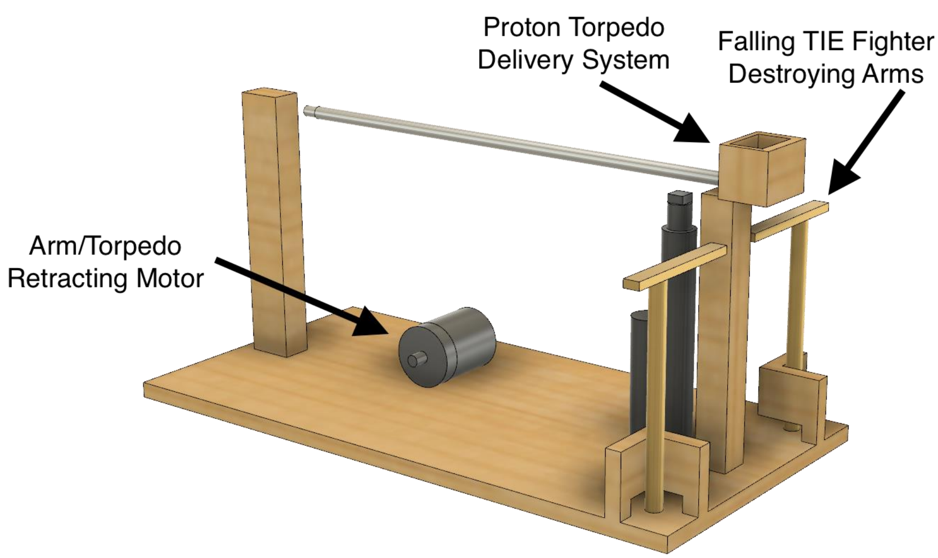


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Figure 7: Stationary Design Alternative

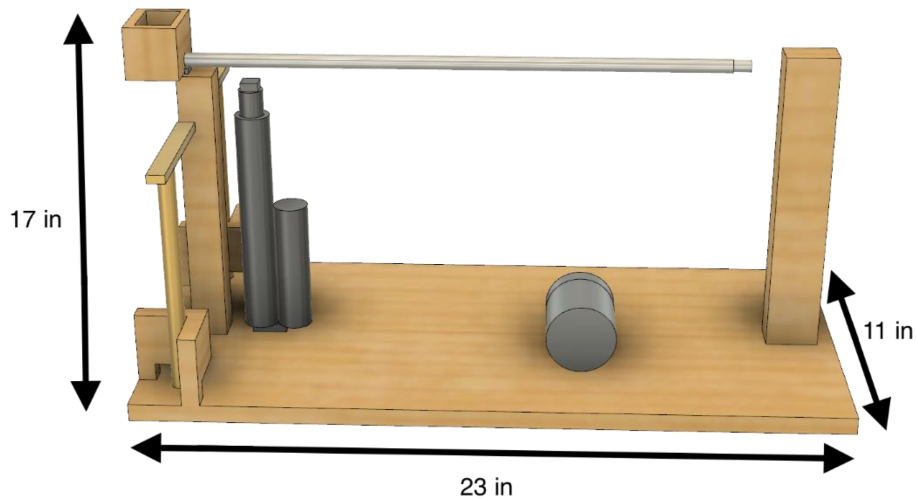


Figure 8: Stationary Design Alternative Side View

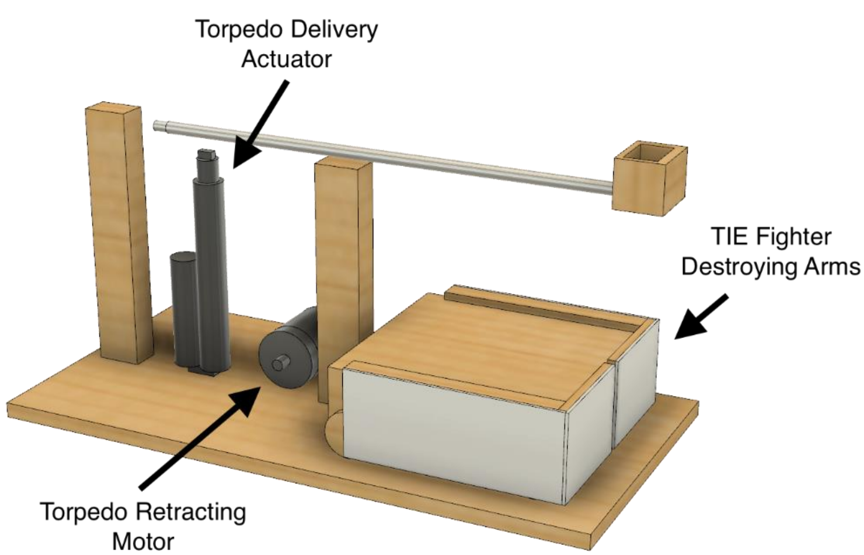


Figure 9: Hybrid Design Alternative

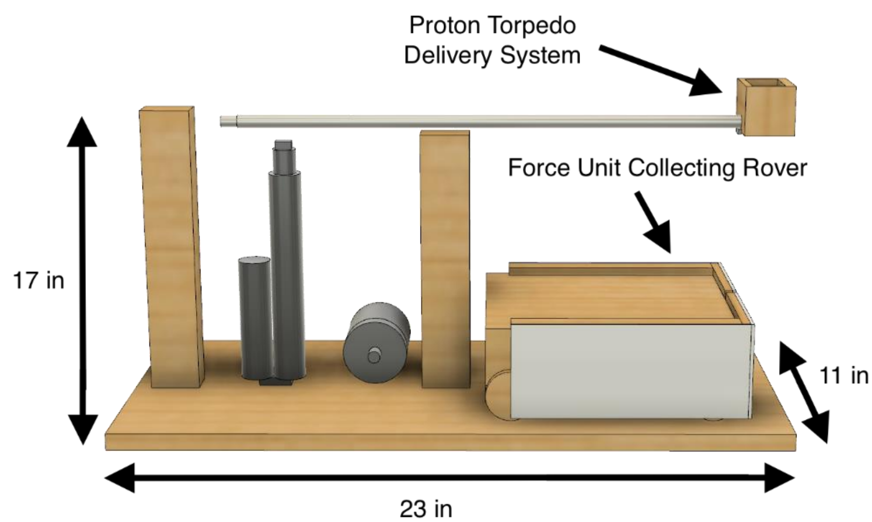


Figure 10: Hybrid Design Alternative Side View

Table 7: Third-Level Evaluation Matrix

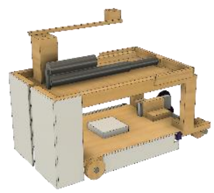
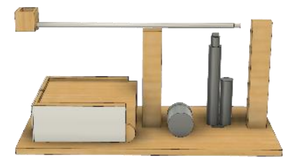
Importance	Customer Requirements			
8	Autonomous Operation	8	8	8
6	Easy to Transport	9	8	4
7	Easy to Setup	7	8	6
8	Quick to Setup	8	8	8
7	Building Material Less Than $100	9	9	9
10	Accomplish Task: Learn to Use the Force	6	5	4
10	Accomplish Task: Learn to Use a Lightsaber	6	6	6
10	Accomplish Task: Destroy the Death Star	8	4	7
10	Accomplish Task: Save the Droids	5	5	5
10	Accomplish Task: Safely Escape the Death Star Explosion	7	8	7
10	Must Fit Within 1ft x 2ft Base Area	9	8	7
10	Height Must be Less Than 18 Inches	9	2	8
8	Must Utilize only Gravity or Power From Board	9	9	9
9	Operate Fully Within 30 Seconds	7	8	6
4	Visually Appealing	9	7	8
5	Easy Assembly	7	5	3

Table #: Caption (cont.)

6	Pickup Within 2.5 Minutes	9	9	7
10	Score Maximum Number of Points per Run	7	7	8
5	Operates Within 3ft Playing Radius	9	9	9
7	Few Set up Steps	9	7	5
7	Destroy Death Star Before Other Team Blocks Pathway	6	8	6
7	Save the Droids Before Other Team	5	5	5
6	Does Not Pollute the Playing Area	9	9	9
5	Prevents Other Teams from Scoring	2	1	3
10	Reliable in its Operation	8	8	8
10	Robust Design for Varying Playing Area Conditions	7	7	7
9	East to Reset Device for Consecutive Runs	5	5	5
8	Shuts Down Operation after 30 Second Operation Time	2	3	2
10	Begins When Start Button is Pressed	7	7	7
5	Does Not Damage Playing Area	7	7	7
5	Does not Cause Wanton Destruction to Other Devices	7	7	7
7	Autonomous Assisted Setup	7	7	7
10	Accomplish Task: Destroy the TIE Fighters	8	5	9
5	Easy to Store	5	5	5
Total		1878	1723	1733
Relative Total = Total/Number of Criteria		0.55	0.51	0.51