Mission to Mars: Final Report

MCHE 201: Introduction to Mechanical Design
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Abstract

The Mission to Mars Robotics Contest is one of three National Robotics Week events in 2017 in the state of Louisiana. As the name implies, the competition simulates an interplanetary mission to Mars through the usage of a small, autonomous robot that uses electrical and gravitational energy. To further dissect the problems that arise and the customer requirements, several engineering tools such as a House of Quality, Specification Sheet, Function Tree, Morphological Chart and Evaluation Matrices were used. The engineering tools make it possible to break down the major task at hand into smaller more manageable tasks while also providing a clear set of customer requirements. After analysis of several possible designs, it is clear that the best design is a two-tiered, double-decker design. The double decker design allows for a more stable frame which can withstand several small variations that naturally accompany each trial. The two-level design also allows for an increase in workable surface area in which mechanisms can rest, as well as visual appeal. The design utilizes a telescoping arm to transport the astronauts and flag to the Mars Base, as well as wheels to decrease the needed extension range to complete certain tasks. The asteroids and fuel are collected by a curved collection arm attached to the front of the device. The extra surface area and ability to accomplish every task set the double decker design far above the others. Ultimately the double decker design performed well leading to a sixth-place finish in the Mission to Mars Robotics Contest. The ingenuity of the telescoping arm and the visual appeal of the two-tier design led to high scores in the judging column, resulting in the second-highest total score.

Good

1 Introduction

The Mission to Mars Robotics Contest is one of three National Robotics Week events in 2017 in the state of Louisiana. As one might deduct from the name, the competition is comprised of a robot which must simulate a transport mission to Mars. During the competition, teams must complete multiple tasks within a “Solar System” and return to the start zone within the allotted amount of time. The Solar System track can be seen in Figure 1 [1]. These tasks include transporting five astronauts—Lego men—to a Mars Landing zone, which if completed rewards a team with five points per astronaut. However, if a team can place the astronauts into a rotating Mars Base towards the center of the Mars Landing zone, then ten points will be rewarded for each astronaut. Another object that must be transported in order to obtain points is a small desk flag. A team can obtain ten points if the flag is completely contained within the Mars Landing zone. Good Not only must each team have to find a way to transport the astronauts and the flag, they also must figure out how to collect and move asteroids and fuel in and out of their zone. Five asteroids—ping pong balls covered in foil—will be randomly placed in each team’s zone at the start of the competition. Once the competition is completed, for each asteroid still in a team’s zone, five points will be deducted. However, if a team can collect these asteroids and bring them to their Asteroid Processing zone, they will be rewarded with five points per asteroid. Another object that can be collected during the competition is Pre-Launched Fuel in the form of plastic toy blocks. There is a total of four Pre-Launched Fuels that can be collected by each team. However, they are placed on the border of each of the team zones, so some teams may end up with none if not collected quick enough. This places a high importance on the fuel collection. For each fuel that is contained completely in a team’s zone, ten points will be rewarded. Also, if a team can collect a Pre-Launched Fuel and get completely out of their zone before time is up, the team will earn an additional twenty points for returning to Earth. Another challenge that teams will face with this competition is being under limited time. So not only do the teams have to perform these tasks simultaneously, they also must do so within thirty seconds.

Challenges other than the actual competition are faced when building and designing a robot. One such challenge is the workable surface area and volume for all the components needed. Although the maximum possible volume is the same for each team, the volume which can be utilized differs according to each design. For understanding the problems of this contest, tools such as a House of Quality, a Specification Sheet, and a Function Tree are useful when looking at details and requirements desired of a specific device. Project planning is a challenge that is overcome through organizing and prioritizing specific tasks. Planning tools such as, a Gantt chart, Prioritization Matrix, and Responsibility Matrix are helpful when trying to break certain tasks down to meet every customer requirement. These are just some of the many challenges that are faced when building and designing a robot for the Mission to Mars Competition. By directly addressing each of these challenges, the final product has a much greater chance of excelling. Section 2 discusses the final design chosen and its functions, followed by an analysis of the problem understanding tools used throughout the design process in Section 3. Good Section 4 presents several alternative designs and the tools used to guide the selection of the final design. The results of the competition and judging can be seen in Section 5. Finally, conclusions are presented in Section 6.

2 Final Design

The final design for the Mission to Mars competition uses a sturdy, double decker design. Similar to the bus which shares the same name, the double decker design includes two major levels of operation, as seen in Figures 2 and 3. This addition of a second level to the device increases the amount of usable surface area and volume, two major issues in regards to the physical building of the device. The second level also helps to increase stability and overall durability. By including a second level, the device can consist of more stable and robust components, adding to its ability to adapt to minor variations that accompany each run. For example, the double decker design is much more likely to withstand an accidental bump from another device due to its support strength of the upper deck. Whereas a single deck design may have a vertical piece break, the double decker channels all impacts to two separate support legs, dampening the impact.

refer to parts by their functional names and match to figures

The lower deck of the double decker, as seen in Figure 4, is largely comprised of the wheel base, allowing for motion, and the curved asteroid collector. Movement of the entire device is achieved through a single, motor-driven wheel which is centered towards the back of the device as well as two smaller freely rotating wheels at the front of the device. The driving wheel is directly attached to the large DC motor, allowing for the smallest room for error in regards to movement. The added movement from the wheels allows for a closer proximity to all possible points, including getting the astronauts to the Mars Base, collecting asteroids and collecting fuel. Therefore, to shorten the necessary operation radius, the entire device moves towards the Mars Base before accomplishing any other tasks.

wheel motor

Good

this is not really a good figure to use here since you're focusing on curvature

Along with the wheel base, the lower deck also functions as the housing for the asteroid and fuel collection mechanism. As seen in Figure 5, the asteroid collector is curved to minimize the inaccessible space in which asteroids could lie. The collector itself is composed of a thin, galvanized steel sheet which is curved to fit the eleven-inch radius of the Mars Landing Zone, which can be seen in Figure 6 [1]. The asteroid collector is attached a small wooden plank by clear fishing line. When the wooden arm rotates, tension is created in the line, causing the collector to move relative to the arm. To rotate the wooden arm, the small DC motor is fitted into the arm. The cutout at the front of the base, as seen in Figure 7, is also essential for asteroid collection. The cutout allows for the device to get closer to the Mars Base without running into the asteroids in the solar system. Therefore, when the asteroid collector is lowered into place, the asteroids will not be wedged up against the Mars Landing Zone. Without the cutout, the asteroids become very hard to effectively mine due to their proximity to the Mars Landing Zone. Attached to the ends of the asteroid collector are two fuel collection arms, responsible for moving fuel into the Solar System. A deployed fuel collection arm can be viewed in Figure 8. As shown, attached to the edge of the asteroid collector is a small wooden support which allows for a servo motor to be mounted. A fuel collection arm made of a light-weight balsa wood is attached to each servo. As the asteroid collection mechanism is lowered, each fuel collection motor rotates, moving the collection arms outward. This places the arms in front of the fuel on either side of the Solar System. Once the device starts moving backwards, the arms intersect the fuel, dragging it into the Solar System.

The upper deck on the two-tier final design largely consists of the device responsible for transporting the flag and astronauts to the Mars Base. As seen in Figure 9, the major mechanism used is a telescoping arm which is powered by a spool attached to a stepper motor. As the stepper motor rotates, the spool spins. A string is attached to the spool. The arm extends or retracts depending on the direction of rotation. The interior of the telescoping arm can be seen in Figure 10. The arm consists of two concentric PVC pipes with a string running between the two. Each pipe has one hole drilled into the edge which the string can run through. The string is also glued to the interior of the smaller pipe to eliminate slippage. As the spool is turned, the string running along the exterior edge of the outermost pipe is shortened. To compensate for this movement, the interior pipe which the string is glued to accelerates forward as the length is shortened. This causes the action seen in Figure 11. At the end of the innermost pipe is a lightweight metal box in which the astronauts and flag rest. Before loading the astronauts and flag, the interior pipe is spun several times. This causes the string to twist around the interior pipe. As the string is shortened along the exterior of the larger pipe from the spool, the interior pipe naturally rotates due to the wrapping of the string. This occurs since the string wants to shorten along the path of least resistance. After the interior pipe is extended halfway, the path of least resistance becomes a combination of rotation and extension of the interior pipe. Thus, the smaller pipe completely rotates. This allows for the astronauts and flag to be dumped without the need for another motor, decreasing the room for ~~robotic~~ error.

3 Problem Understanding

To understand all the challenges and problems that are faced when in the design process for the competition, certain design tools are utilized. Although there is no specific "ideal" robot since there is no guarantee that a robot will work completely as expected one hundred percent of the time, a team can get very close to what is desired by breaking down every large task into a much more manageable version. This is done through design tools such as a House of Quality, a Specification List, and a Function Tree. In the House of Quality shown in Table 1, customer requirements and engineering characteristics are analyzed to see the correlation between any combination of requirement and characteristic. The majority of the most important customer requirements directly reflect the rules and regulations of the competition itself. But, in regards to the possible point tasks, importance must be weighted based on assumption of how each task is related to one another. For example, being able to collect fuel directly affects the ability to return to Earth. Therefore, collecting fuel is more important than collecting asteroids. Collecting fuel is also highly important due to the location of the fuel cells since each device has a limited number of cells in its immediate surroundings. The House of Quality also shows the correlation between two engineering characteristics. This is shown in the Correlation Matrix which is the roof of the house. For example, one engineering characteristic is to minimize the number of parts used for the robot, which correlates strongly with minimizing the total cost of the robot. This is shown by placing two plus signs where the two characteristics intersect. Each customer requirement is ranked on its importance, and the correlations between the engineering characteristics and the customer requirements are given numerical values and calculated to see the importance of those as well. Several of the most important engineering characteristics are self-explanatory, such as "average number of points scored" and "average number of tasks completed" since they directly reflect the goal. However, some of the most important engineering characteristics are not as obvious, such as operation radius. Its high relative importance of 7.0 percent, shows how much time should be spent focused on this characteristic. The high importance of operation radius is due to the fact that

a bit "fluffy"

Good

so many of the tasks revolve around a point outside of the immediate surroundings of the start zone. Therefore, to accumulate the most points, a large operation radius is necessary.

~~Another useful design tool is~~ the Specification Sheet, ~~which~~ ~~allows a team to set goals and must haves for each of the engineering characteristics. This design tool~~ separates the details of a design into categories and assigns a "D" or a "W" to them to signify if that certain engineering trait is a demand or want. For example, in Table 2 under geometry, one of the details which is labeled as a demand is "less than 18 inches in height." This is the case due to the regulations of the competition. If this specification is broken, a disqualification occurs, giving it the utmost importance. Another detail listed under the geometry category states that the robot must be "less than 17 inches in height," and is a want by the design team. While this specification would be nice to have, if it is not accomplished, the design could still be valid. The Specification Sheet is used to set a rough outline for all the design ideas to follow. If any design violates a demand, it not a valid design and should therefore be discarded. or modified?

The last tool which aids in understanding the problems relating to the Mission to Mars Competition is the Function Tree. This design tool allows a team to break up large, difficult parts of the design functionality into much smaller parts, as seen in Figure 12. By breaking down the larger tasks, the process becomes more achievable. Rather than looking at a big picture with multiple complex tasks at hand, several straightforward tasks can be addressed individually. As these smaller tasks are completed, they begin to build up to the big picture. less of this
The idea of the Function Tree is to break down each function until only the simplest version of each task remains. For example, although "place astronauts in base," is a very broad task, more of this
using the Function Tree, the task can be broken down into several more achievable tasks such as "sense location of astronauts in relation to base."

4 Concept Evaluation

When designing a device, many things must be considered depending on what the desired goal is. For instance, many different structures allow for different results. Size and curvature are a couple of details that vary between different structures. When in the design process, many ideas need to be considered, and if some of those ideas are not efficient enough to accomplish the goal, alternative designs must be created. To get a clearer image of each idea, a Morphological Chart is used. As seen in Table 3, several tasks can be achieved using multiple mechanisms. This realization helps to create a more efficient overall device that is capable of accomplishing multiple tasks much quicker than otherwise possible. where do these tasks come from?

One of the alternative designs is based on a child's game known as *Hungry Hungry Hippos*. In this game, a hippo's mouth lifts open and reaches forward to grab small balls on the playing board. This device's design replicates the hippo in that a wall is raised and engulfs the asteroids similar to the game. A motor is attached to a rod to make it rotate and allows a metal bar to be pushed horizontally through grooves in two wood pieces, seen in Figure 13. This allows a structure, like the hippo's mouth, to be lifted and move towards the center of the team zone to collect asteroids. The asteroids are brought back to the Asteroid Processing zone and the structure is lifted back up over the asteroids. This device base never leaves the start zone, eliminating the need to return. The astronauts and flag are delivered in a cup with a cardboard bottom attached by a servo motor. This cup is attached to the end of a wooden accordion arm, seen in Figure 14, that stretches the length of the zone until it reaches the center of the Mars

Landing zone. Once at the Mars Landing zone, the servo motor moves the cardboard bottom, allowing the astronauts and flag to drop. However, this device did not have a valid structure to collect the pre-launched fuel, and therefore is not able to achieve maximum points.

The other alternative design is a device that acts as a small cart. This four-wheeled device, as seen in Figure 15, moves towards the center of the zone using a fixed back axle. On the sides of the device are arms that sweep out once it is turned on. This mechanism allows the device to collect the asteroids and the pre-launched fuel from the zone when the device is moving forwards. As seen in Figure 16, a cylinder is attached to the top of the device, similar to the hippo design. This is where the astronauts and flag are kept until delivery. Also, similar to the hippo, the cup has a cardboard bottom attached via a servo motor. Once the device reaches the Mars Landing zone the servo motor moves the cardboard bottom and releases the astronauts and flag. Before the thirty seconds is up, the device will move backwards with the collected asteroids and pre-launched fuel until it returns to the start zone.

These two alternative designs can achieve some of the goals but are inconsistent when it comes to others. This can be shown by a design tool known as an Evaluation Matrix, as seen in Table 4. This design tool allows the different devices to be compared to one another to see their strengths and weaknesses. Listing the customer requirements and rating each device on how well they met those customer requirements allows the Evaluation Matrix to show which device was most sufficient. For example, in Table 4, it shows that the final design has the highest ratings in importance when it comes to the customer requirements. The double decker design scored higher in most categories due to its straightforward approach to most of the tasks at hand. For example, by eliminating another motor to drop the astronauts and flag, the double decker design eliminates room for error. This gives the double decker design an advantage not only in the "transport astronauts" category but also allows it to run many more times consecutively without the risk of breaking. The double decker design is also much stronger than the other two designs when it comes to fuel collection due to its ability to collect both fuels consistently in one easy movement. Where the other two designs are limited in their ability reach out to access the fuel, the final design is wider and more compact, granting it easier access to the fuel. The double decker design is weaker than the other two designs in regards to being lightweight, yet due to weight not being a highly important customer requirement, this does not play a large role in its overall performance. Because of the double decker's ability to accomplish several important customer requirements, such as collecting fuel and consistent performance, it is the strongest design as shown by the Evaluation Matrix.

Good

Good

5 Design Performance Evaluation

During the competition, the device's performance was very good, coming in sixth place overall. Typically, performances in competitions do not always go as planned. Of course, there were some mishaps where the device did not perform as intended, but for the most part, it did what was expected. Occasionally the arm that transported the astronauts and the flag did not rotate a complete three hundred and sixty degrees, which limited how many astronauts were dumped out. Other times, the asteroid collector, caught the lip of the Mars Land zone and was not able to collect the asteroids as intended. This was due to a misaligned starting position. Due to the many small track variations, perfecting the starting placement took a few rounds. Once the starting location became more apparent, the device ran almost perfectly, winning most rounds

informal

in first place. Sometimes the device ran perfectly and earned the maximum points intended. This included the astronaut arm rotating a complete three hundred and sixty degrees and allowing the astronauts and flag to be dumped out, the asteroid collector mining all asteroids, and the fuel collection arms collecting at least one, sometimes two, fuel cells. Towards the beginning of the competition, there was a slight mishap in which one of the fuel collection arms fell off. However, due to the design's simplistic, straightforward approach, the arm was easily fixed prior to the next round of competition. Throughout the rest of the competition the device continued to run smoothly and ultimately made it to the semifinal round. Ultimately the major factor that lost the competition was a lack of a backup plan in regards to collecting fuel and interacting with other devices. During the semifinal, the device interacted with the adjacent robot, stopping the device from being able to collect asteroids or fuel.

Not only did the double decker device do well in the actual competition, but also in the judging portion of the competition. Due to its unique telescoping arm, the device was seen as very ingenious. The arm, which is different than any other arm used in the competition, negated the need for an additional motor to release the astronauts and flag. This creative idea regarding the arm and the stacked look is what set the device apart in the judges' eyes. The device also scored highly in aesthetics mainly due to its double decker look. While the device was not painted excessively, the paint on the main body added a professional feel to an already straightforward device. The double decker design also allowed for many unappealing aspects such as the astronaut arm spool and RedBoard to be hidden underneath the second deck.

how did it rank?

After the competition concluded, the flaws in the design and thought process became obvious. Some assumptions made during the design process were correct while others were not. One of the correct assumptions was that the device would run differently every time, depending on which track the device was placed on. Since each of the tracks are slightly different in structure and distance, it is difficult for the device to have the exact same result every time. However, the magnitude of the flaw was not properly adjusted for in the final design. This was one of the downfalls during the contest. It led to inconsistent collection of the asteroids during the early rounds. It also led to a less than perfect performance in the consolation round since the device had to be run on an entirely new track. One possible solution that would have fixed the issue is an infrared sensor on the front of the device to identify how close it is to the Landing Zone. Another incorrect assumption was that the other devices would be slower than the double decker design in regards to fuel collection. If this had been considered as a customer requirement, then the final design may be slightly different. Instead of targeting the two interior fuel cells, which appeared the be the more popular, the design would have targeted the exterior fuel, avoiding the need for quick collection. Despite several incorrect assumptions, the device performed very well achieving sixth place in the competition and second in judging.

Good

6 Conclusion

The most successful design is the two-tier design due to its surface area advantage as well as being able to accomplish each task slightly better than the other two designs. The use of a moving device helps to minimize the room for error that comes with multiple far reaching parts, while the telescoping arm transports the astronauts and flag while also remaining compact. The curved asteroid collection arm also gives an advantage through its ability to form a tight fit around the edge of the Mars Landing Zone.

Be more concise. this is a long conclusion section for a report of this length.

Coming up with a design that is capable of a Mission to Mars is a challenge within itself. Within this process are little tasks which create more challenges. These tasks range from challenges to accomplish in the actual competition, to the physical limitations of the engineering process. Some of the challenges in the actual competition are things such as, carrying and delivering astronauts and a flag to the Mars Landing Zone, collecting or voiding asteroids and Pre-Launched Fuel within a team zone, and doing all of this within a thirty-second-time frame. Other challenges are identified with design tools such as, a House of Quality, a Specification List, and a Function Tree. These tools allow for a clearer picture of the tasks at hand and functions needed to accomplish each. Other tools used such as the Morphological Chart and Evaluation Matrix helped to establish and compare several different designs. Through a comparison with the customer requirements, the Evaluation Matrix helps to identify the best design based on its ability to fulfill each requirement. Due to its ability to accomplish so many customer requirements, such as collecting fuel and performing consistently, the double decker design was the strongest despite it not being very light in comparison with the others.

Ultimately, the device performed extremely well, placing sixth overall in the competition and second in judging. The sleek, two-tiered design appealed to the judges as being very professional while not overly extravagant. It also scored highly with respect to ingenuity due to the telescoping arm. The lack of a need for a motor was very different from every other device, setting it apart. A solid understanding of the device and clear communication also helped to separate it in respect to presentation. During the competition, the first few rounds had some issues in regards to the starting position. This made it difficult to collect asteroids, putting the device into the loser's bracket rather quickly. However, once the starting issue was corrected, the device performed extremely well, winning every round until the semi-finals. The consistency of the asteroid arm and fuel collection set the device apart from the rest of the competition. The fatal flaw of the device was a lack of a backup plan when collecting fuel. If the fuel was collected by another team, the device had no way of collecting the two fuels closer to the start zone. This flaw was induced by the incorrect assumption that most devices would take the full thirty seconds to complete the tasks at hand. Yet, despite this, the robot excelled, landing among the best.

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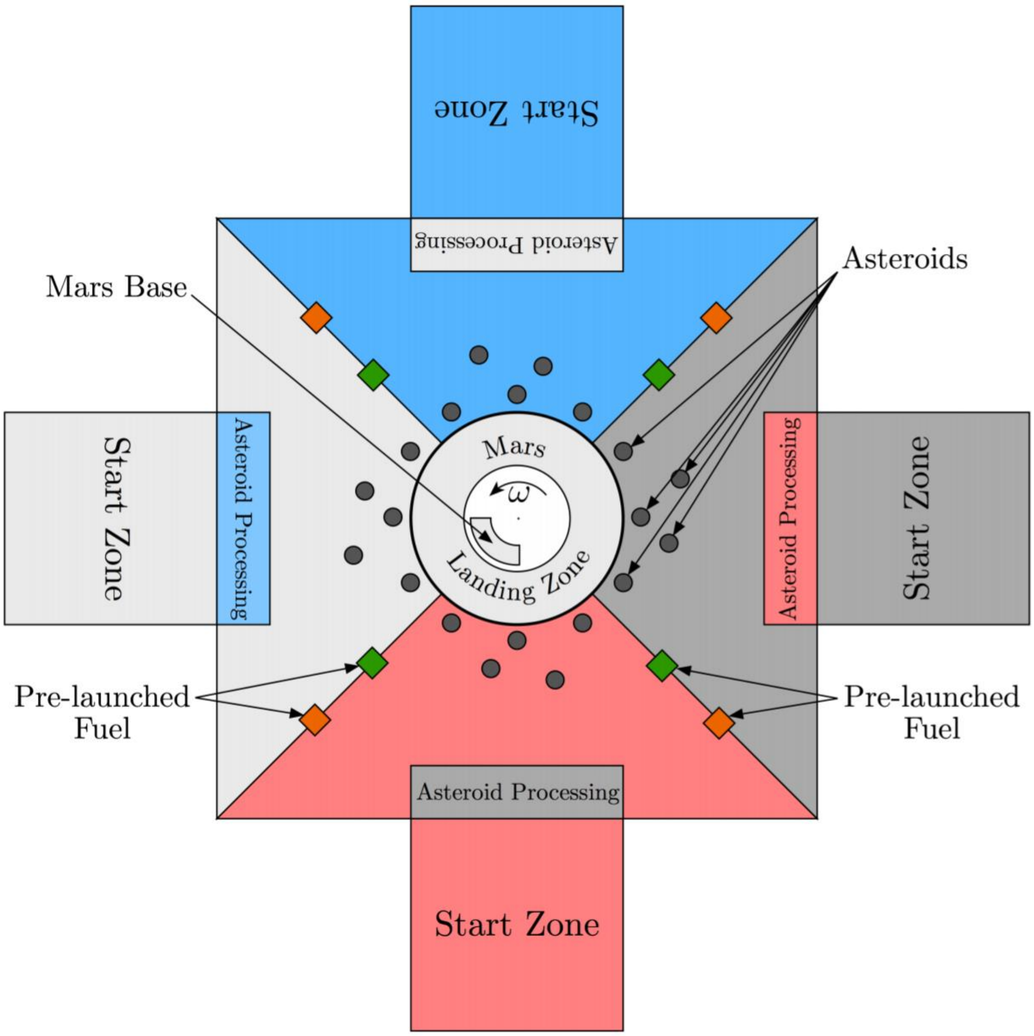

Figure 1: Solar System Track [1]

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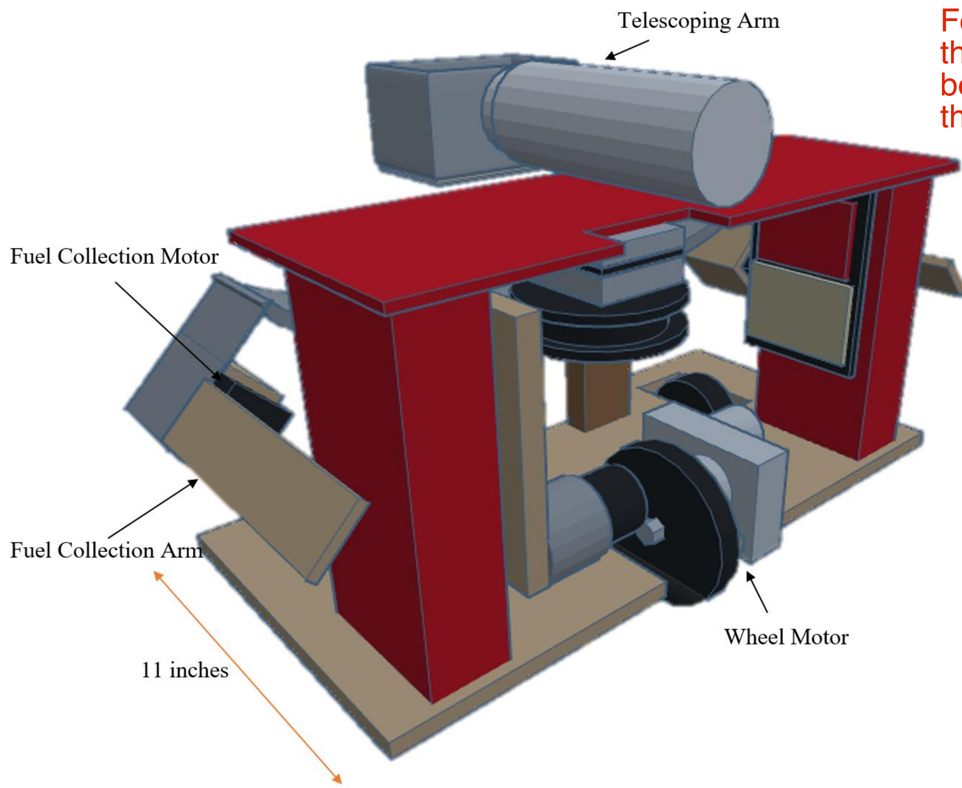


Figure 2: Angled View of Two-Tier Double Decker 3D Model

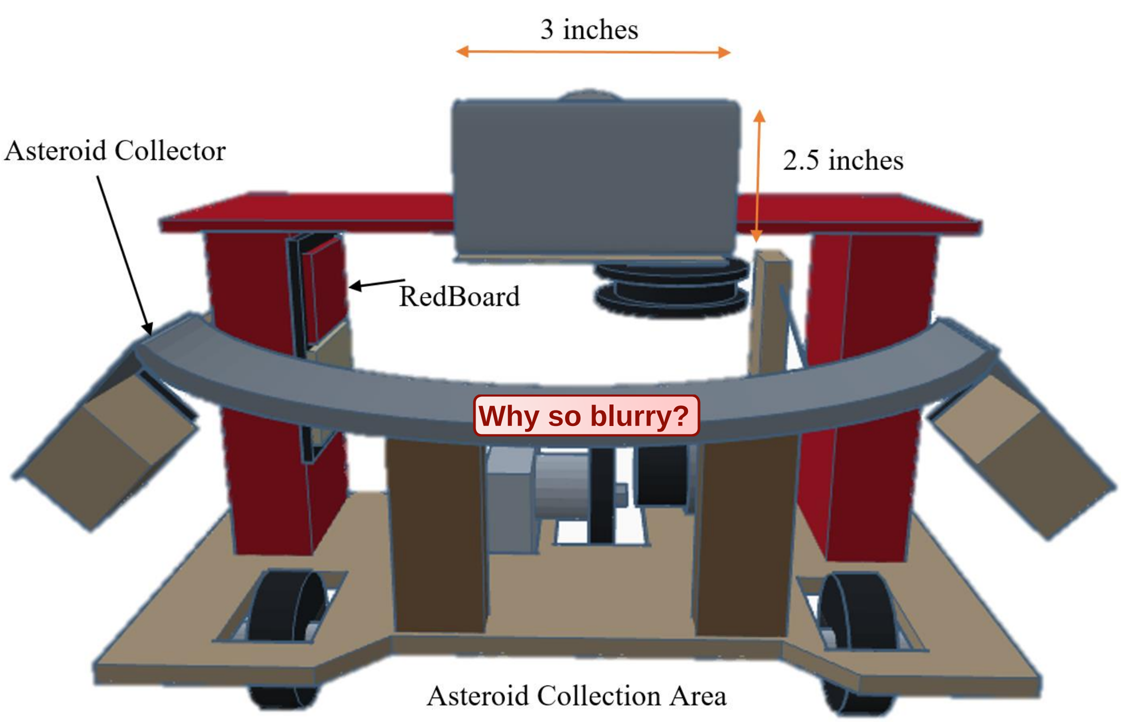


Figure 3: Front View of Two-Tier Double Decker 3D Model

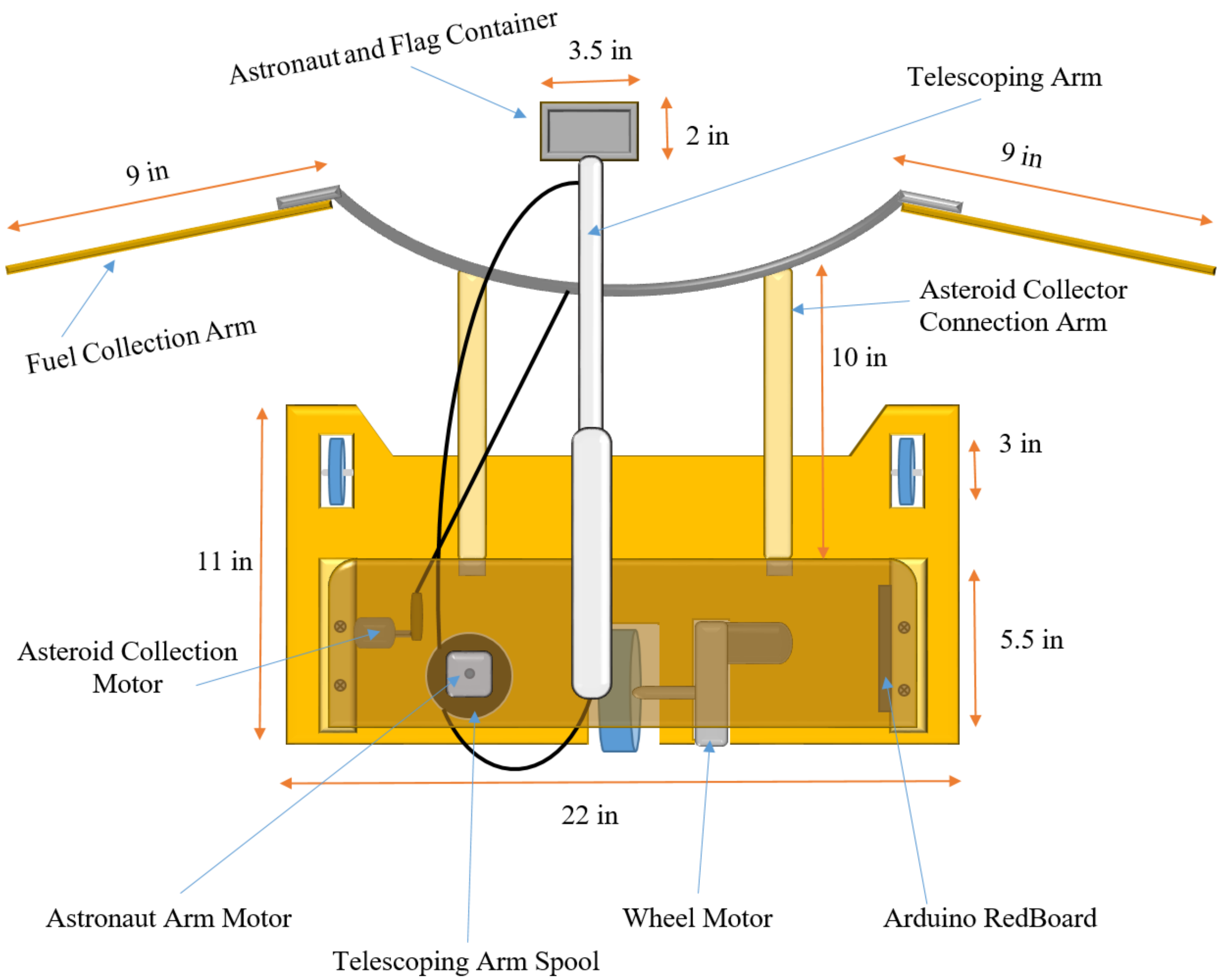


Figure 4: 2-D Aerial View of Double Decker Design

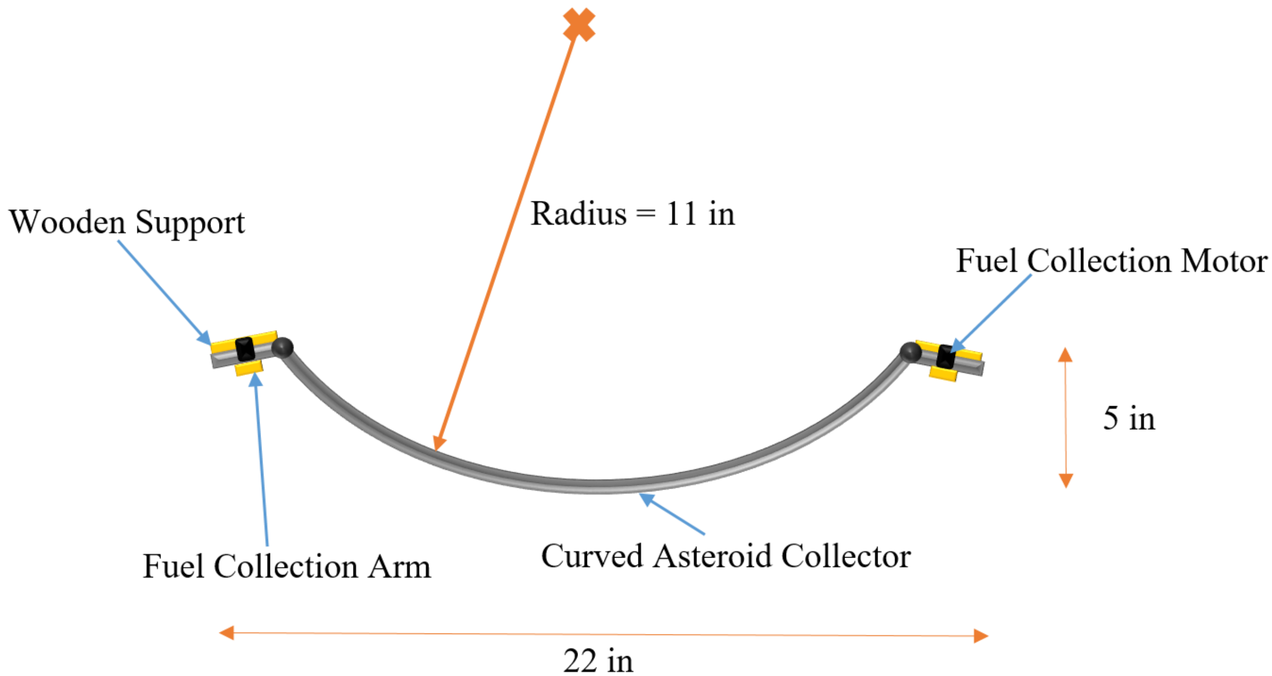


Figure 5: Curved Asteroid Collector

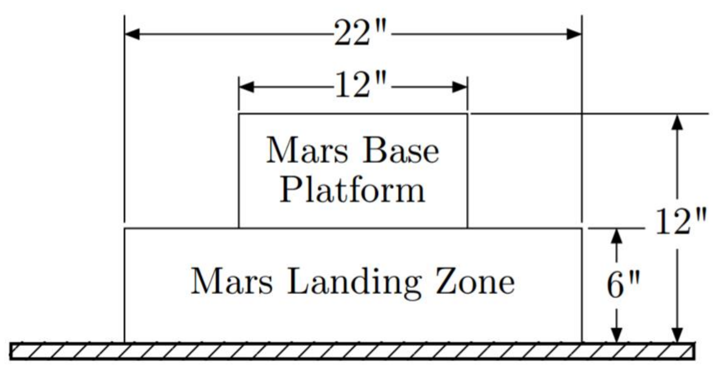


Figure 6: Mars Landing Zone Dimensions [1]

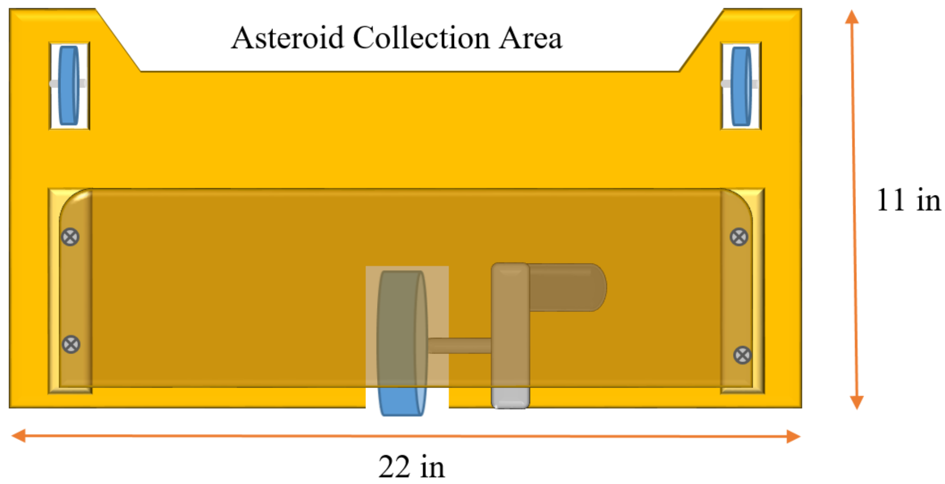


Figure 7: Asteroid Collection Area Aerial View

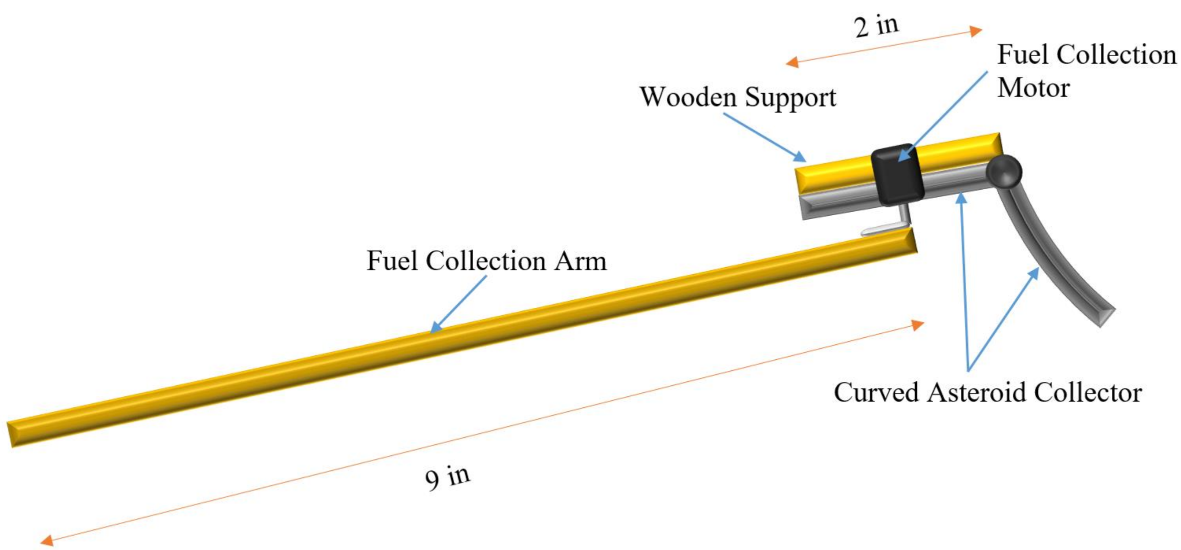


Figure 8: Aerial View of Fuel Collection Arm

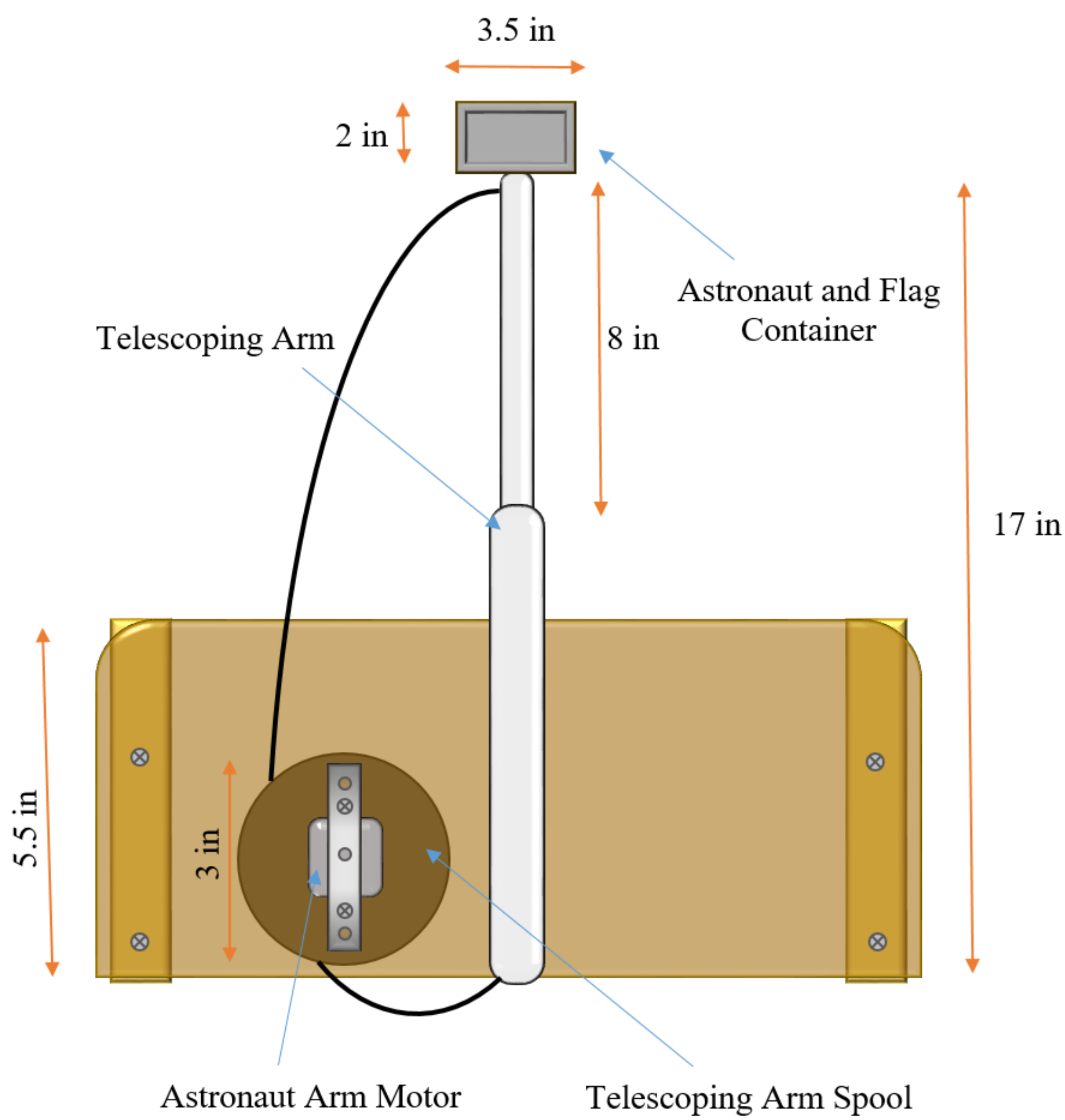


Figure 9: Aerial View of Upper Deck

font too small

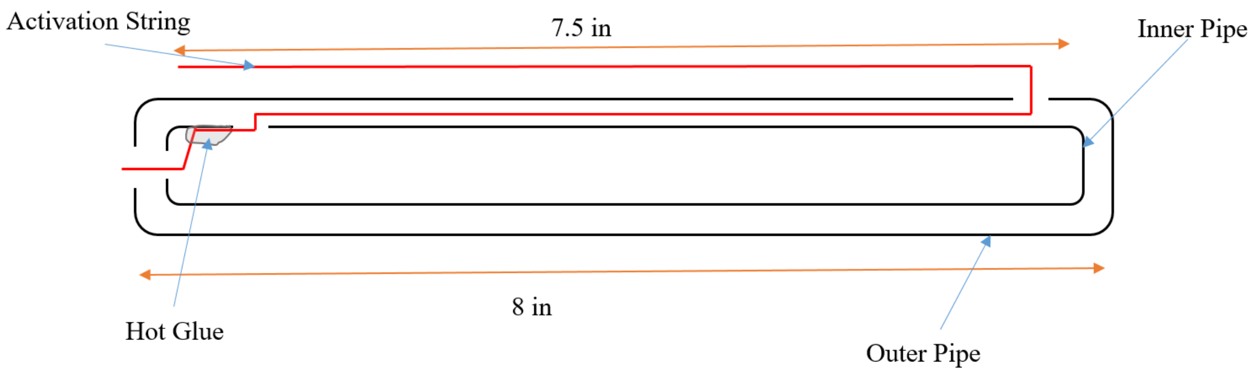


Figure 10: Skeleton View of Compressed Telescoping Arm

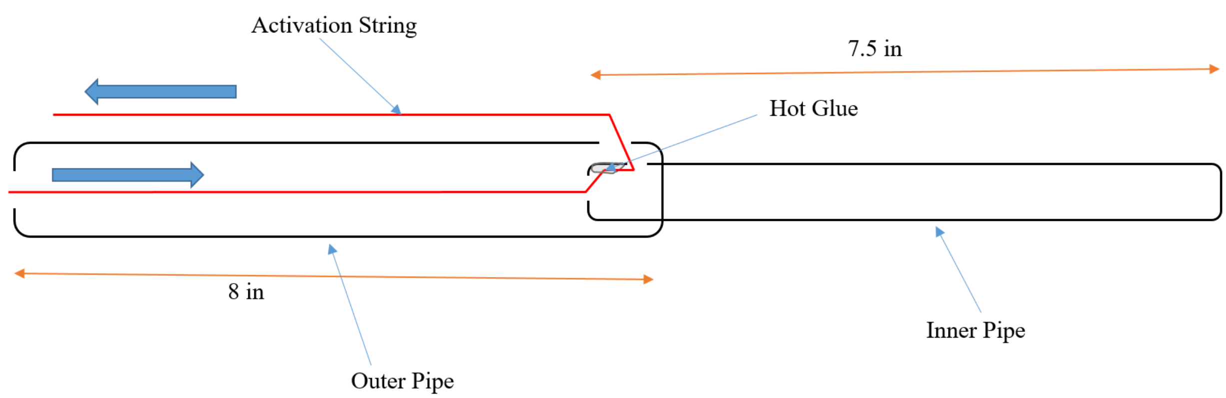
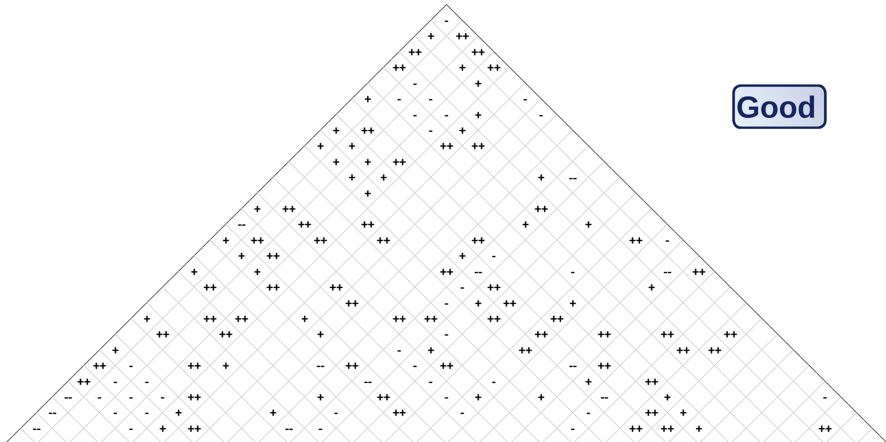


Figure 11: Skeleton View of Expanded Telescoping Arm

Table 1: House of Quality



Good

Symbol	Meaning
◉	Strong
▣	Medium
△	Weak

Symbol	Meaning
++	Strong Positive
+	Positive
-	Negative
--	Strong Negative

Symbol	Meaning
▲	Maximize
▼	Minimize
x	Target

Importance	Customer Requirements \ Engineering Characteristics	Weight of the entire device	Height of the undeployed device	Width of the undeployed device	Length of the undeployed device	Number of parts	Time needed to set up	Time needed to take down	Total cost	Average distance of astronauts from base	Number of electrical components	Number of asteroids remaining in the solar system	Average distance of flag from landing zone	Number of components to disable opponents	Average number of points scored	Volume of space occupied by undeployed device	Total time needed to complete tasks	Operation radius	Number of programmed steps	Number of steps needed to set up	Consistency for each task completed (%)	Average number of tasks completed	Average number of astronauts transported	Time taken to begin operation	Time needed to build	Time needed to reset device	Frictional forces between moving parts	Time needed to collect fuel	Surface area of the device
	Direction of Improvement	▼	▲	▲	▲	▼	▼	▼	▼	▼	▼	▼	▼	▲	▲	x	▼	▲	▼	▼	▲	▲	▲	▼	▼	▼	▼	▼	▲
10	Transport astronauts to the Mars base		▣		△				△	◉	▣		▣		◉		▣	◉	▣		▣	◉	◉	△			▣	△	▣
9	Plant a flag in the landing zone		▣		△				△	▣	▣		◉		◉		▣	◉	▣		▣	◉		△			▣	△	▣
9	Avoid asteroids		△	▣	▣				△		▣	◉			◉	△	▣	◉	▣		▣	◉		△			△	△	△
7	Collect asteroids		△	▣	▣				△		▣	◉			◉	△	▣	◉	▣		▣	◉		△			▣	△	▣
10	Collect fuel		△	▣	▣				△		▣				◉	△	▣	◉	▣		▣	◉		△			▣	◉	▣
10	Return to Earth	△		△	△				△		▣				◉		◉	△	▣		▣	◉		▣			▣	◉	△
10	Cost less than $100					▣			◉		▣			▣											▣				
6	Lightweight	◉	△	△	△	▣	◉	◉	△	△			△		△	▣	▣			△		▣	△	△	△	◉	▣	△	◉
4	Visually appealing		△	△	△				▣		△					◉									▣				△
10	Set up within 4 minutes	◉	▣	▣	▣	△	◉	▣			◉			▣	▣				△	◉		△				◉			
5	Easily transported	◉	▣	◉	◉	△	▣	△			△			△		◉				▣					△				◉
10	Autonomous operation									◉	◉	▣	◉		▣				◉		▣	◉	◉	◉			△		
7	Can run multiple times without breaking	▣	△	△	△	△			▣						▣			△			△				▣	▣	▣		
7	Stays in the solar system	△		◉	◉					▣				△	△			◉					△						△
4	Few parts	▣	△	△	△	◉	▣	△	◉		▣			◉		▣									◉	△			
10	Can be picked up within 2.5 minutes	◉					▣	◉		▣	▣		▣	▣	△	△				△									△
5	Few number of electrical components					△	△	△	◉	△	◉	△	△		△			△	◉	▣	△	▣	△			◉	△		
10	Completes tasks in less than 30 seconds	△								▣	◉	▣	▣		▣		◉	▣	▣	▣	▣	◉	◉	◉			◉	◉	
10	Score maximum number of points						▣	▣		◉	◉	◉	◉	△	◉		◉	◉	▣	▣	◉	◉	◉	▣	△	▣	△	◉	▣
8	Prevent other teams from scoring			△	△						△	△		◉	△	△	△	▣						△					
6	Fast build time	▣	▣	▣	▣	◉			△		△			△		▣									◉				◉
7	Few number of programming steps									▣	◉	▣	▣	▣					◉	△			△	△		◉			
10	Does not harm other devices or people	▣	△	△	△		△					△		▣			▣	▣						△					
8	Easy to reset	△				▣	▣	△		△	▣		△	△	△	△			△	◉			△			◉			▣

Table 1: House of Quality (continued)

9	Can be run multiple times with consistent results		△	△	△		△		△	◉	▣	◉	◉		◉		▣		▣		◉	◉	◉	◉	▣	◉	△	▣	
6	Few number of set up steps					△	◉	△						△					△	◉						◉			
10	Length is less than 24 inches	△							△	▣		△	▣			▣		◉				△	▣		△			△	◉
10	Width is less than 12 inches	△		◉					△			△				▣		◉				△			△			△	◉
10	Height is less than 18 inches	△	◉						△	◉			▣			▣						△	▣		△				◉
9	Starts as soon as the circuit is closed									▣	▣		▣		◉		◉		△		△	▣	▣	◉					
10	Does not move after the 30 second time frame										▣			△	▣		◉		△								△	△	
9	Does not leave materials behind			△	△			◉						△				◉		△					△				
10	Does not damage competition area	◉										△		△				▣							△				
7	Large usable surface area	▣	▣	▣	▣		△	△		▣					▣	△	▣	◉				◉			△	△			◉
3	Few free-moving parts					◉	△				▣										△								
9	Collects fuel quickly	▣	△	△	△	△						△			◉		▣	△			◉	◉					▣	◉	▣
	Absolute Importance	563	306	421	350	231	343	320	310	667	845	458	559	320	1034	278	707	1027	493	338	501	1090	561	478	277	521	347	539	715
	Relative Importance	3.8564	2.096	2.8838	2.3974	1.5823	2.3495	2.1919	2.1234	4.5688	5.7881	3.1372	3.829	2.1919	7.0827	1.9042	4.8428	7.0347	3.3769	2.3152	3.4317	7.4663	3.8427	3.2742	1.8974	3.5687	2.3769	3.692	4.8976

better to start this on a new page

Table 2: Specification Sheet

Good

		Specification for:	Issued:	2/22/2017
		Final Project	**Page 1 of 1**	
Changes	**D/W**	**Requirements**	**Responsibility**	**Source**
		Design a multifunctioning, autonomous robot		
		Geometry		
	D	Less than 18 inches in height	Design Team	Contest Rules
	D	Less than 24 inches in length	Design Team	Contest Rules
	D	Less than 12 inches in width	Design Team	Contest Rules
	W	Less than 17 inches in height	Design Team	Design Team
	W	Less than 23 inches in length	Design Team	Design Team
	W	Less than 11 inches in width	Design Team	Design Team
	W	Operates at least 2 ft from the starting point	Design Team	Design Team
	D	Operates at least 1 ft from the starting point	Design Team	Design Team
		Kinematics		
	~~W~~	~~Top speed of 3 m/s~~	~~Design Team~~	~~Design Team~~
3/28/2017	W	Top speed of 1 m/s	Design Team	Design Team
	W	Robot stops movement within 1 second of code signal	Design Team	Design Team
	~~W~~	~~Acceleration greater than 1 m/s~~	~~Design Team~~	~~Design Team~~
3/28/2017	W	Acceleration greater than 0.5 m/s^2	Design Team	Design Team
		Forces		
	~~W~~	~~Weight of overall device less than 10 lbs.~~	~~Design Team~~	~~Design Team~~
3/28/2017	W	Weight of overall device less than 8 lbs.	Design Team	Design Team
	~~D~~	~~Weight of overall device less than 40 lbs.~~	~~Design Team~~	~~Design Team~~
3/28/2017	D	Weight of overall device less than 20 lbs.	Design Team	Design Team

Table 2: Specification Sheet (continued)

		Materials		
	D	Robot contains no more than 2 DC motors	Design Team	Contest Rules
	D	Robot contains no more than 1 stepper motor	Design Team	Contest Rules
	D	Robot contains no more than 3 servo motors	Design Team	Contest Rules
	W	Robot contains less than 100 separate parts	Design Team	Design Team
		Signals		
	D	Robot begins within 3 seconds of start signal	Design Team	Design Team
	W	Robot begins within 1 second of start signal	Design Team	Design Team
		Safety		
	D	Reactivity level of zero	Design Team	Contest Rules
		Assembly		
	W	Less than 10 set up steps	Design Team	Design Team
	W	Set up takes less than 3 minutes	Design Team	Design Team
	D	Set up takes less than 4 minutes	Design Team	Design Team
	D	Take down takes less than 2.5 minutes	Design Team	Design Team
	W	Take down takes less than 1.5 minutes	Design Team	Design Team
	W	Robot takes less than 7 days to build	Design Team	Design Team
		Transport		
	W	Robot consists of less than 5 transportation pieces	Design Team	Design Team
		Operation		
	W	Interacts without contact with any other robot	Design Team	Design Team
	W	Astronauts average within 6 inches of the base	Design Team	Design Team
	D	Astronauts average within 2 feet of the base	Design Team	Design Team
	W	Flag averages within 6 inches of the base	Design Team	Design Team
	D	Flag averages within 2 feet of the base	Design Team	Design Team
	D	Robot operates within 3 foot perimeter	Design Team	Contest Rules
	D	Robot stops opeation in less than 30 seconds	Design Team	Contest Rules
	~~W~~	~~Robot completes tasks within 28 seconds~~	~~Design Team~~	~~Design Team~~
4/20/2017	W	Robot completes tasks within 22 seconds	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	Design Team
	W	Robot averages more than 80 points scored	Design Team	Design Team
		Costs		
	D	Extra materials cost less than $100	Design Team	Contest Rules

Good

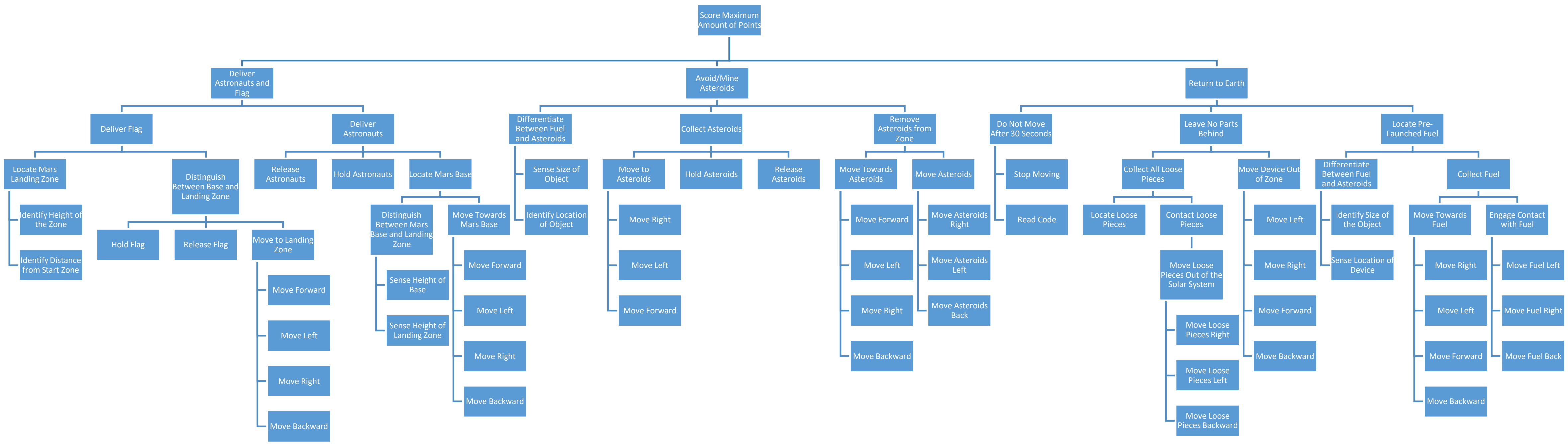
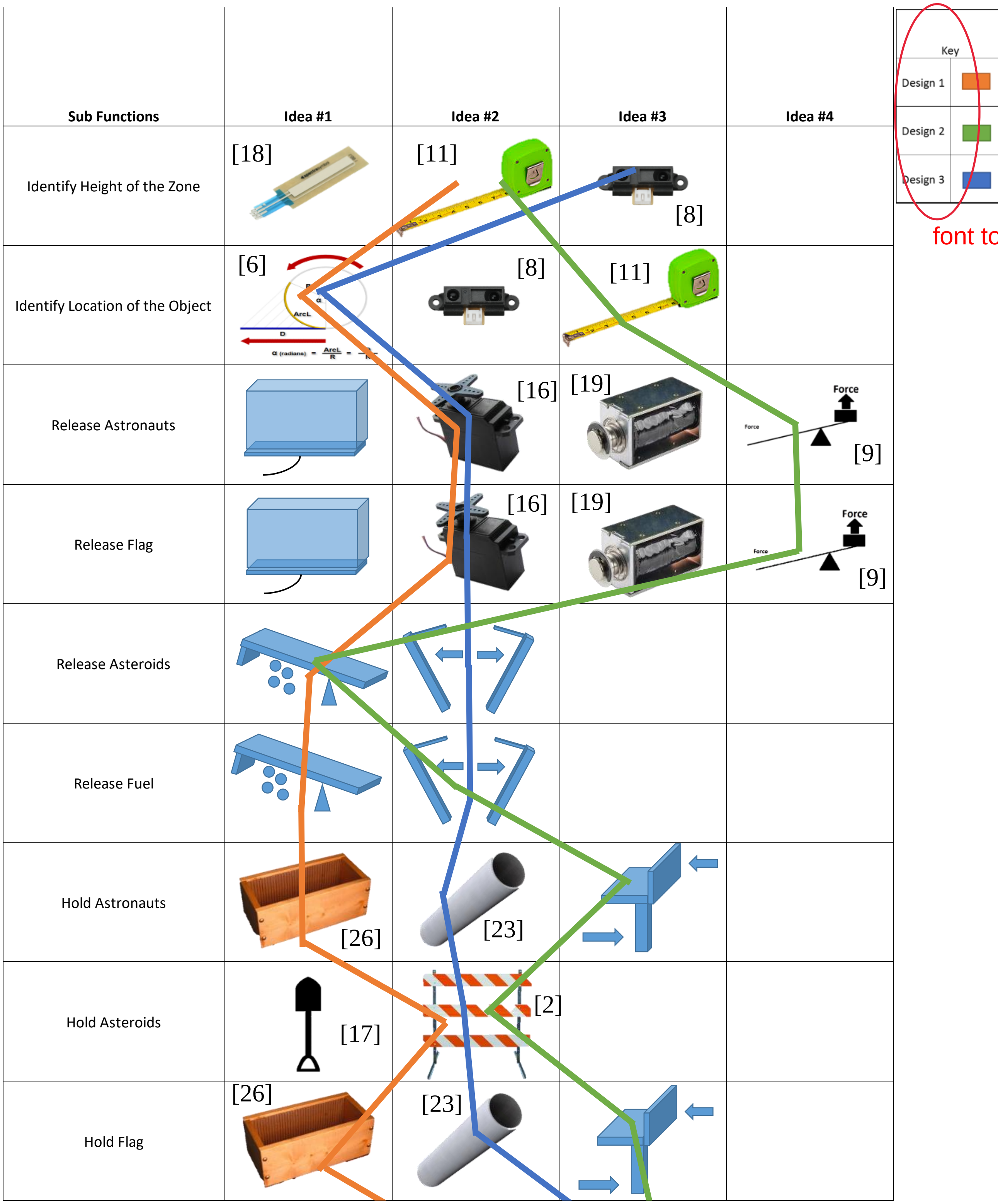


Figure 12: Function Tree

Table 3: Morphological Chart



Sub Functions	Idea #1	Idea #2	Idea #3	Idea #4
Identify Height of the Zone	[18]	[11]	[8]	
Identify Location of the Object	[6]	[8]	[11]	
Release Astronauts		[16]	[19]	Force Force [9]
Release Flag		[16]	[19]	Force Force [9]
Release Asteroids				
Release Fuel				
Hold Astronauts	[26]	[23]		
Hold Asteroids	[17]	[2]		
Hold Flag	[26]	[23]		

Key	
Design 1	(orange)
Design 2	(green)
Design 3	(blue)

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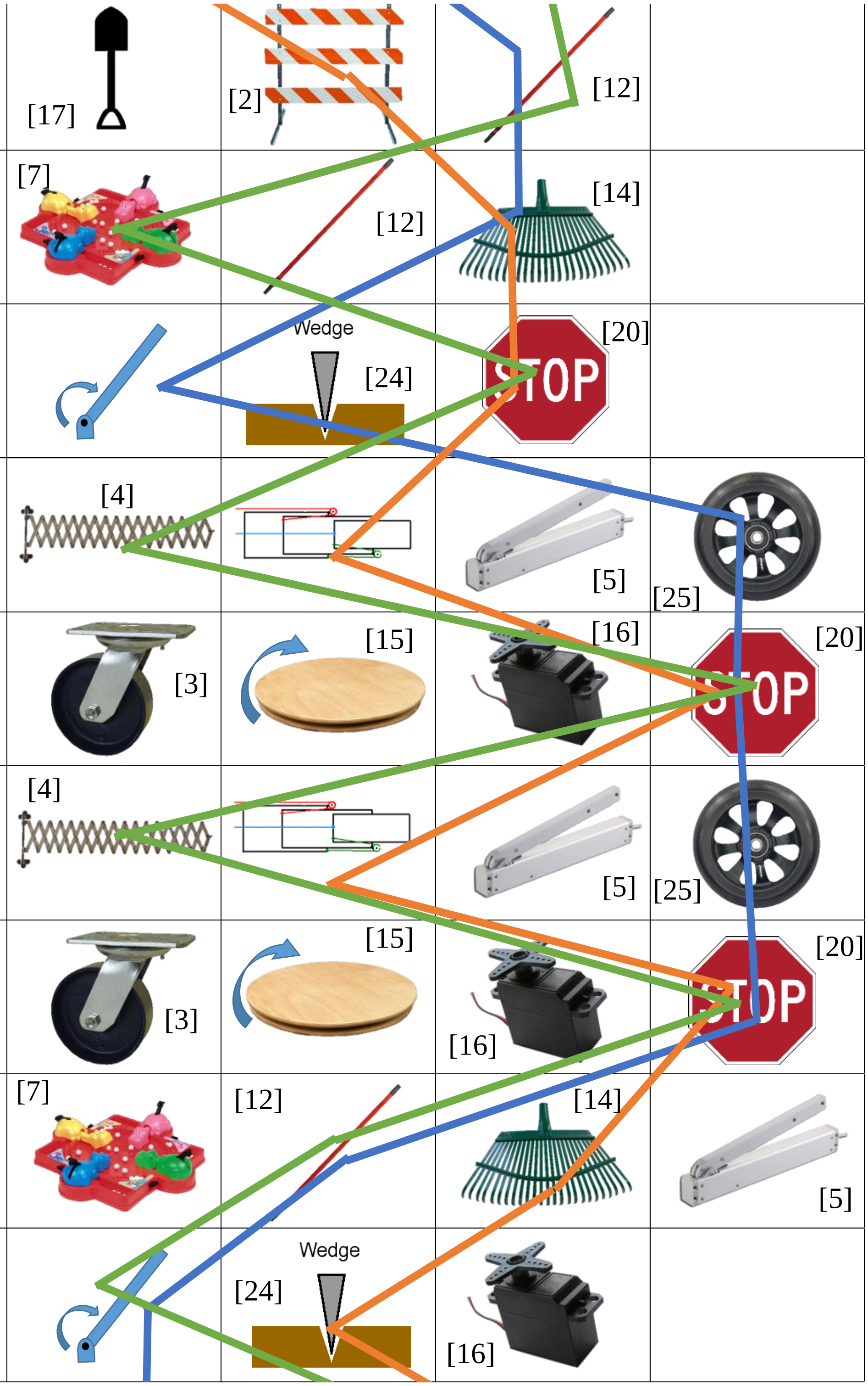
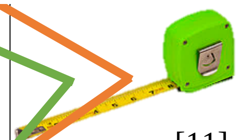
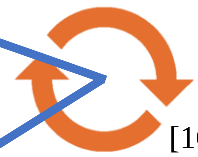
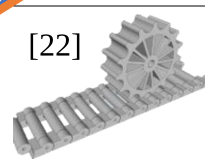
increase font here, you have plenty of space

Table 3: Morphological Chart (continued)



Hold Fuel	[17]	[2]	[12]	
Move Asteroids Forward or Backward	[7]	[12]	[14]	
Move Asteroids Right or Left		Wedge [24]	[20]	
Move Astronauts Forward or Backward	[4]		[5]	[25]
Move Astronauts Left of Right	[3]	[15]	[16]	[20]
Move Flag Forward or Backward	[4]		[5]	[25]
Move Flag Left or Right	[3]	[15]	[16]	[20]
Move Fuel Forward or Backward	[7]	[12]	[14]	[5]
Move Fuel Left or Right		Wedge [24]	[16]	

Table 3: Morphological Chart (continued)

Sense Size of the Object	[8] 	[18] 	 [11]	
Stop Moving	 [13]	[21] 	 [10]	
Move Device Left or Right	 [3]	[20] 		
Move Device Forward or Backward	[25] 	[22] 	[20] 	

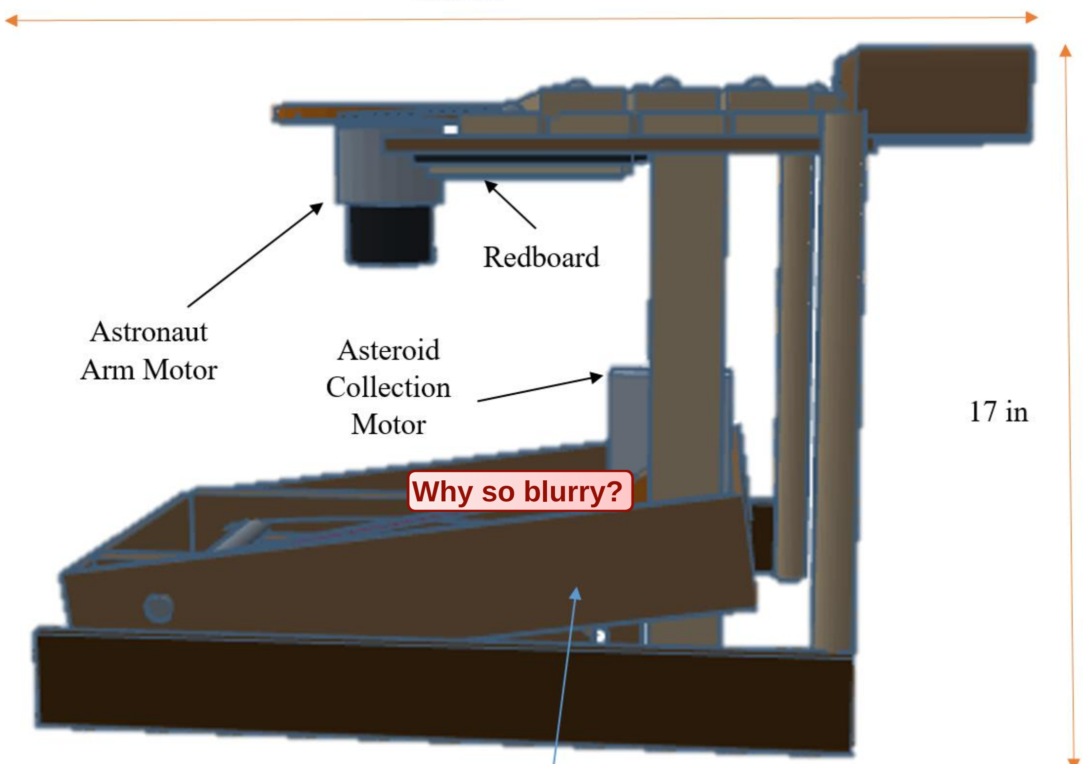


Figure 13: Hippo Asteroid Collector Side View

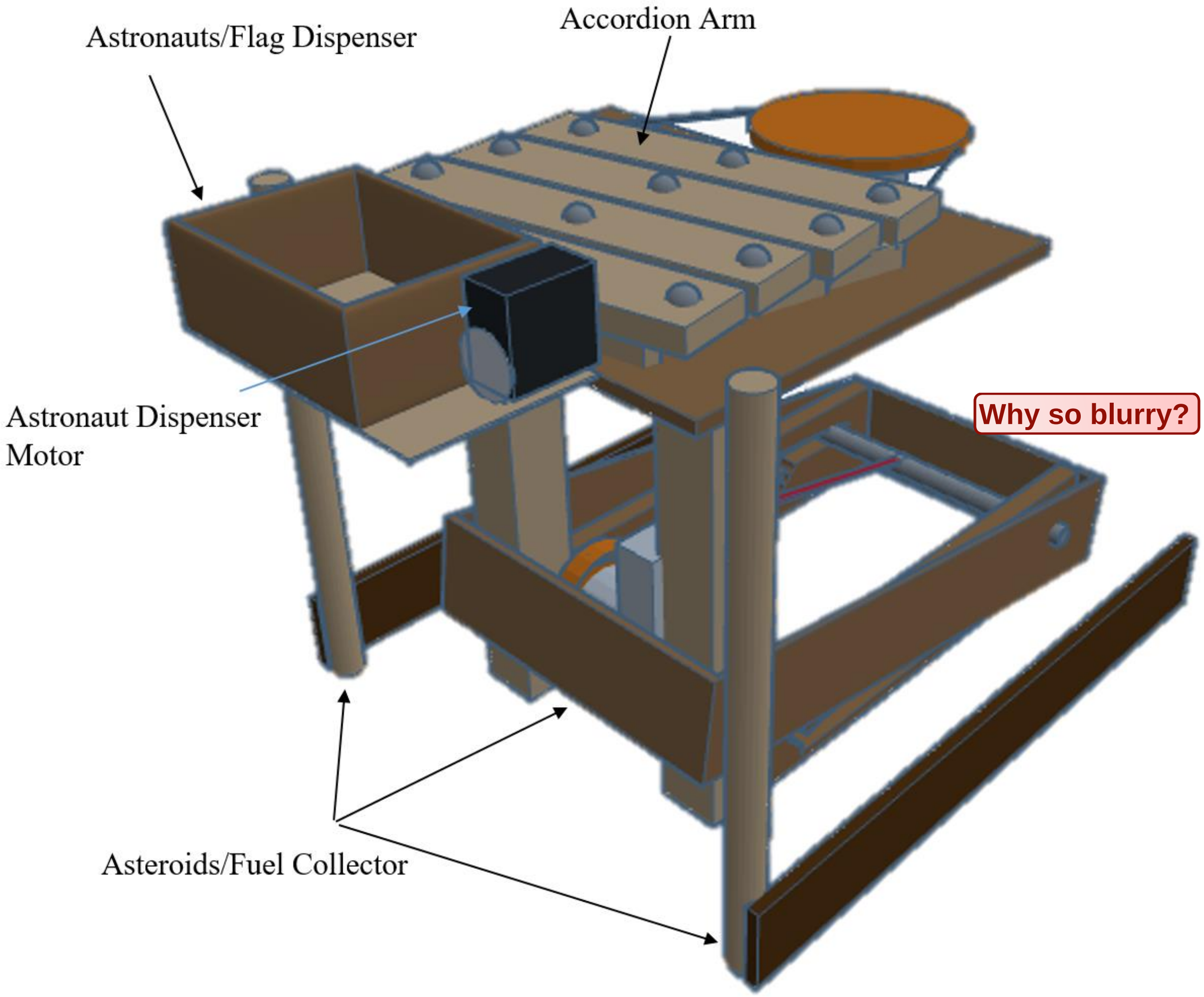


Figure 14: Hippo Accordion Arm

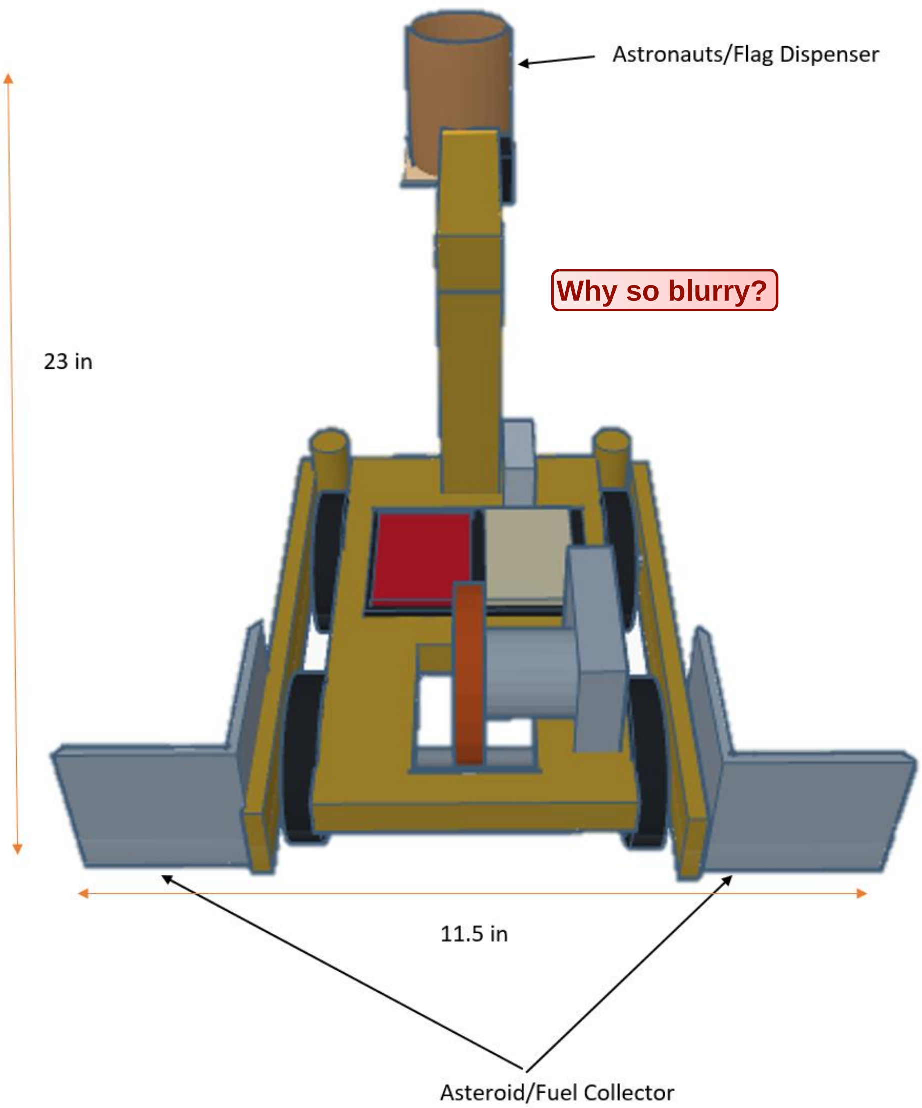


Figure 15: Rear View of Cart Design

Why so blurry?

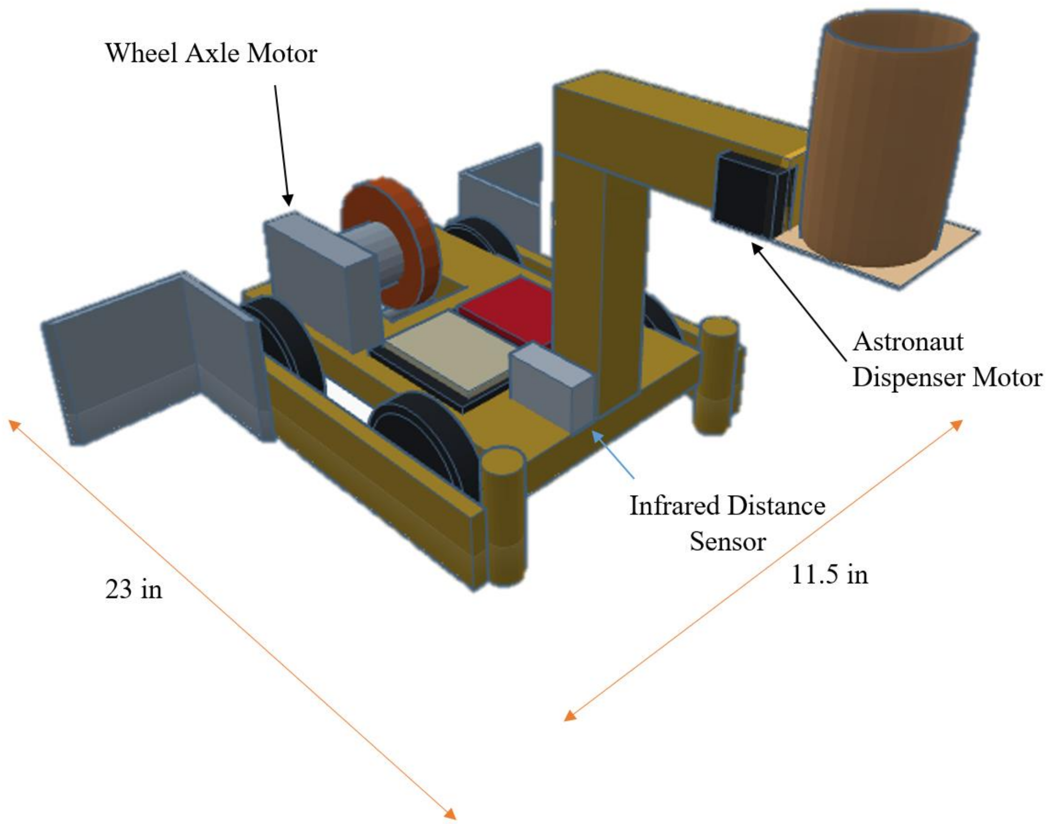
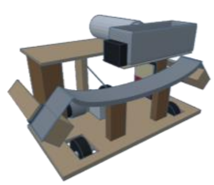
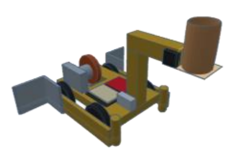


Figure 16: Angled View of Cart Design

Good

Table 4: Third Level Evaluation Matrix

Importanace	Customer Requirements			
10	Transport astronauts to Mars base	6	4	5
9	Plant a flag in the landing zone	9	9	4
9	Avoid asteroids	10	7	5
7	Collect asteroids	10	7	3
10	Collect fuel	8	2	2
10	Return to Earth	9	10	6
10	Cost less than $100	10	10	10

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

avoid splitting, just
put on one page

Table 4: Third Level Evaluation Matrix (continued)

6	Lightweight	7	7	10
4	Visually appealing	8	7	7
10	Set up within 4 minutes	9	7	10
5	Easily transported	8	6	9
10	Autonomous operation	10	6	9
7	Can run multiple times without breaking	9	5	4
7	Stays in the solar system	8	8	6
4	Few parts	9	3	9
10	Can be picked up within 2.5 minutes	9	7	9
5	Few number of electrical components	7	5	8
10	Completes tasks in less than 30 seconds	9	8	6
10	Score maximum number of points	8	6	5
8	Prevent other teams from scoring	2	0	0
6	Fast build time	6	5	8
7	Few number of programming steps	7	5	7
10	Device does not harm other devices or people	10	10	10
8	Easy to reset	10	10	10
9	Can be run multiple times with consistent results	8	3	5
6	Few number of set up steps	8	5	8
10	Length is less than 24 inches	10	10	10
10	Width is less than 12 inches	10	10	10
10	Height is less than 18 inches	10	10	10
9	Starts as soon as the circuit is closed	10	9	9
10	Does not move after the 30 second time frame	9	9	9
9	Does not leave materials behind	10	9	8
10	Does not damage competition area	10	10	10
	Total	2396	1975	2014
	Relative Total = Total/Number of Criteria	0.73	0.60	0.61