Mission to Mars

Final Report

MCHE 201: Introduction to Mechanical Design
Spring 2017

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Abstract

This report discusses the performance of the robot JEB2 (Jonathan, Ezra, Barron, Team B2) that was built for the MCHE 201 final project. The robot needed to autonomously complete a series of tasks that includes placing five LEGO Minifigures and a small flag into a "landing zone" that is moving in a circular path, moving "asteroids" (ping-pong balls covered in foil) out of the robot's zone, obtaining "pre-launch fuel" (bringing small blocks at the edge of the zone

not necessarily, just need to be out of team's zone

into the robot's zone), and safely returning to Earth (returning to the start zone). For initial understanding of the objective, design tools such as a house of quality, specification sheet, and function tree were used. Three conceptual designs were created and evaluated, one with wheels, one with tracks, and one that remained in the start zone. Using an evaluation matrix comparing the three conceptual designs, the conceptual design with wheels to move forward was most efficient in meeting the customer requirements. It turned out to be the most reliable design due to its simplicity relative to the other designs. There were less points for failure in this design, and since the robot is supposed to be able to repeat the tasks for multiple rounds, it is best to have one that is not at a high risk of failure. The other two designs would have more complex structures and therefore have more possibilities for failure to occur. The robot finished seventh out of twenty-four teams, which is adequate. The competition ended coming down to how each robot interacted with the robots to its sides. ~~JEB2 could have easily done much better, but it also could have done much worse.~~ Judging results?

which one is JEB2?

capitalize tool names

stay formal

fewer

stay formal

I. Introduction

Explain what's in the figures. Tell your reader where to look and what's important in them.

Use the same capitalization as the full rules (especially with quotes) “Transport Astronauts to the Mars Base”

Cite the figure source here too, not just in the caption.

A robot was designed and built to complete multiple tasks in a competition against other robots and was required to meet certain specifications. There were three other robots (four in total) on the track each round. The layout and dimensions of the track are shown in Figures 1, 2, and 3. The theme of the competition is “Mission to Mars”. The robot was ~~supposed to be able~~ to complete five main tasks. The first task is to “transport the astronauts to Mars”. This task entailed transporting five LEGO Minifigures to the “Landing Zone” centrally located on the track. Extra points were awarded if the LEGO Minifigures dropped into the “Mars Base” which rotates in the center of the “Landing Zone”. The second task was to get a small flag into the Landing Zone. The third task was to remove or mine the “asteroids,” which are ping pong balls covered with aluminum foil. Points were awarded for each asteroid contained within the designated “asteroid processing” zone at the end of the round. Points were deducted for each asteroid remaining anywhere else in the robot’s zone. The fourth task was to collect “pre-launched fuel”, which are small blocks, placed on the border between each zone. Points were added for each block fully inside the robot’s zone. More points were added after the final task was complete if the robot ended the round in its start zone or anywhere on the track outside of the team’s zone. However, teams were only eligible to receive these points if at least one piece of “pre-launched fuel” had been collected. There were a few strict specifications the robot was required to meet. The dimensions that the robot must fit within were 12” X 24” X 18”. Ideally, it should be smaller, but it certainly cannot be any larger. The robot had to operate autonomously and utilize one RedBoard from a SparkFun Inventor Kit. The cost of materials for the robot could not exceed one hundred dollars excluding the cost of the MCHE 201 kit components provided by the instructor. The MCHE 201 kit components provided by the instructor included a motor driver shield, large DC gearmotor, small DC gearmotor, stepper motor, solenoid, IR sensor, power supply and its connector, as well as banana plug connectors. The robot’s strict specifications and the number of tasks it was expected to complete presented multiple challenges. After a thorough analysis of the problems, three main concepts were created and evaluated.

Such as? What were the engineering challenges?

The next section will discuss the final design. Section 3 discusses the design tools used to understand the problem. Section 4 will discuss the two alternative designs and reasoning for choosing the final design. Section 5 discusses the end performance of the robot. The last section will conclude this report.

Good

II. Final Design

The final design that was chosen can be seen in Figure 4. The final build is shown in Figure 5. The robot’s name is JEB2, derived from the first letter of each team member’s name and the team name (Jonathan, Ezra, Barron, Team B2). The robot is a three-wheeled model consisting of a lightweight PVC pipe frame designed to roll forward consistently regardless of ~~in the event that the robot encounters~~ any inconsistencies on the track’s surface. The pieces of ~~the~~ PVC pipe frame also play a role in giving the design a highly stable structure. The frame is tall enough in height and its arm is long enough in length for it to simply roll forward and be able to reach over the Mars Landing Zone to drop off the LEGO Minifigures in the Mars Base without having to adjust its height.

To operate autonomously, code was written for the robot which was uploaded onto a SparkFun RedBoard, attached to the base of the robot’s frame. The large DC gearmotor, small DC

Not exactly true... 120VAC
is converted to 12VDC by
the power supply.

gearmotor, and stepper motor are powered by a standard 120V power outlet which connects from the track to the motor driver shield. This supplies power to the RedBoard as well as the robot's components. The large DC gearmotor is responsible for moving the robot forward and backward. A single office chair wheel acts as the main driving force for the robot. The wheel is directly attached to the shaft of the large DC gearmotor. As the shaft spins, its motion rotates the wheel, causing the robot to move forward or backward. The office chair wheel was selected as the driving force due to its ideal size and rubber surface. The rubber surface of the wheel ~~has~~ is ~~just the right balance of hardness and softness, allowing it to be~~ both sturdy enough to carry the robot and ~~have~~ has enough traction to efficiently move JEB2 with little to no slippage.

The small DC gearmotor is attached to the front of the frame, where it has a small metal holster connected to its shaft used to hold the flag. When the shaft of the small DC gear motor rotates, the small metal flag holster tips over, allowing the flag to slide off, once the robot moves forward enough to be in range of the "Landing Zone". The final design makes use of each of the three allowed servo motors. A piece of cardboard,which is attached to a single servo motor is used as a base to hold the LEGO Minifigures. When the servo motor rotates, it moves the piece of cardboard out from beneath the PVC cup extending from the front of the robot allowing the LEGO Minifigures to drop into the Mars Base. ~~One~~ Two additional servo ~~motor is~~ motors are attached to each of the two front corners of the design. Both servos have one asteroid sweeping arm attached to its motor shaft. These Asteroid Sweeping Arms were created using four zip ties bound tightly together with tape. The zip ties were chosen because of the ~~flex~~ flexibility they give when the arms hit the landing zone in front of it. The stepper motor is attached to the side of the robot, and its purpose is to swing an arm out to collect the "pre-launched fuel" into the robot's zone. A wooden arm constructed with a hook on the end is secured to the shaft of the stepper motor, which swings out after the robot moves forward. Once the Robot lowercase is moving backward, the arm hooks the "pre-launched fuel" and drags it back into the robot's zone. After the robot has completed all the required tasks that it was coded to complete, it safely returns to earth (the start zone).

Use
consistent
capitaliza-
tion

III. Problem Understanding

To design a robot capable of winning the Mission to Mars competition, customer requirements and engineering characteristics must be evaluated. Design tools were used to fully understand the problem at hand in order to build a successful design. The House of Quality, shown in Table 1, relates the customer requirements to the engineering characteristics. The House of Quality greatly aids in deciding which customer requirements and engineering characteristics are of greatest importance and should be emphasized most. Some customer requirements with high importance included a maximum height of 18 inches, maximum operation time of 30 minutes, and avoiding any disqualifications. Some engineering characteristics that had a high relative importance included total operation time, codes that can be run 10 consecutive times, and the height of the robot. why 10? The correlation between the customer requirements and the engineering characteristics ~~is extremely important.~~ Understanding ~~said correlation~~ helps prioritize the engineering characteristics in the design process.

The Specification Sheet in Table 2 lays out all the specifications that the robot must meet. Each specification is labeled with either a "D" meaning it is a demand the design must satisfy or a "W" which signifies a want of the team. A few demands in order to create a successful design include meeting the dimension restrictions of ~~less~~ no more than 12" X 24" X 18". A want is something the customer would like to have such as weighing less than redundant

15lbs. Wants are specifications that do not necessarily have to be met in order to create a successful design, but would ideally contribute to a better overall robot. ~~Having everything laid out in an orderly fashion greatly helps further prioritization.~~

The Function Tree shown in Figure 7 evaluates all the tasks the robot needs to complete to achieve the main goal, ~~which in this case was to~~ win the Mission to Mars competition. Some of the main tasks, such as "transport men to Mars Base" and "sweep asteroids", were simplified into smaller and smaller sub functions to something much less complex, such as "move forward" or "read codes". Breaking down these main functions into smaller tasks help provide a better understanding of the problem as a whole. This is a critical tool to use when deciding the best method of designing the robot to complete the tasks. ~~After thorough examination and editing of these design tools, the concepts in the next section were made.~~

Avoid chronological construction

IV. Concept Evaluation

Two alternative concepts were evaluated in the design process, the Tank Design and the Stationary Design. Figure 7 shows the Tank Design that functions with tracks to move. The design is built to move forward to transport the LEGO Minifigures using tracks that help it overcome any inconsistencies the track may possess. It is equipped with a blade similar to that of a bulldozer located on the front of the robot, used to collect the asteroids and process them. On the robot arm, a servo motor is responsible for moving the LEGO Minifigure container to release the men in the Mars Base.

Exacly match the labels on the figures to this text.

Figure 8 presents the Stationary Design. This design ~~differs from the other two in that the concept of this design~~ is a robot that never moves from the start zone. It uses a large DC gearmotor to extend its retractable arm. A servo is secured to the front of the stationary frame with an asteroid sweeper arm, composed of tightly bound zip ties, attached to the servo motor. When the servo motor is commanded to move, it swings out the asteroid sweeper arm and pushes the asteroids out of the zone.

The Evaluation Matrix in Table 3 shows how well each concept meets each of the customer requirements and compares the three designs to each other. The matrix lists all the customer requirements and scores each design based on how ~~they fulfill~~ it fulfills these requirements. For example, the requirement to travel forward was scored higher based on its completion for the JEB2 design and the Tank Design, where as to the Stationary Design scored lower on this requirement because it does not move. The JEB2 design, however, had a slight edge on the Tank Design because it used a simpler form of transportation. The JEB2 design used wheels instead of tracks like the Tank Design. The use of tracks requires more mechanical parts. The use of tracks rather than wheels can be beneficial, but for the Mission to Mars competition, pairing a limited number of motors with a strict budget leaves the Tank Design prone to error and malfunctions. In a competition where one mistake can result in elimination, consistency is crucial, and the Tank Design sacrifices this. An error prone design is a reoccurring theme that is also present in the Stationary Design. In this design the moving parts would have to extend a great length, therefore, the connecting parts would have to be capable of withstanding repeated strain. This again leaves room for error in the design, which cannot be afforded during the competition. Less moving parts required for JEB2 make it a more ideal final design choice than the Stationary Design. The Evaluation Matrix tool helps conclude that the chosen JEB2 design best satisfies the customer requirements for the Mission to Mars competition.

although techni-cally part of it does move forward..

refer back to the evaluation matrix to make comparisons (use scores)

V. Design Performance Evaluation

JEB2 ~~performed quite well. Team B2's robot~~ exceeded positioning expectations in the Mission to Mars competition. Following a flawed run in the first round, the robot did well to recuperate and advance through the bracket all the way to the consolation round. In both the consolation round and the previous round, the same robot was competing to the left of Team B2. The path of the other team's arm interrupted JEB2's "pre-launched fuel" sweeping arm's motion in both rounds, resulting in Team B2 not receiving critical points for collecting a 'pre-launched fuel" and returning to the start zone. JEB2 could have done much better if it was coded to grab the piece of "pre-launched fuel" located closer to the start zone. Since it was coded to obtain the fuel closer to the "Landing Zone", it would either get caught up in the adjacent robot or just not get the fuel completely into its zone, therefore not getting the "return to Earth" points. Another option that could have resulted in acquiring the "pre-launched fuel" more consistently would have been a different motion of the sweeping arm. The teams whose sweeping arm operated from the rear of the robot toward the front seemed to get the "pre-launched fuel" more often than those whose sweeping arm swept from the front to the rear, such as JEB2's. Team B2's robot was, however, very consistent with getting the Minifigures and flag into the Landing Zone. Despite its troubles, JEB2 managed to finish in the top third of the competition field, placing seventh out of the twenty-four robots entered in the Mission to Mars competition.

Prior to the competition date, ~~Team B2 made~~ multiple assumptions were made, some of these proved to be correct while other incorrect assumptions contributed to JEB2's elimination. The competition was unexpectedly chaotic. Many of the robots that were very well-designed were eliminated earlier than presumed because they were matched up against other robots that would interact with them in a way that interrupted their robot's planned routine and costed them a large amount of points. There were ~~so~~ many different factors to the competition because of the unlimited design possibilities of the competing robots. It was nearly impossible to be fully prepared for this competition because the way teams advance through the bracket largely plays into the outcome of the competition. Some robots advanced a few rounds by just barely moving and therefore were able to not get disqualified, while competing robots were disqualified. If JEB2 was coded differently, it might have been able to do better, but at the same time, something else could have happened that could have made JEB2 do worse.

Another possibility that was assumed was that some teams would struggle with inconsistencies in the track. While, this problem did not have a huge role in the outcome of event, it did contribute to the elimination of a few teams. JEB2's design was solid in this area and had no issues maneuvering any obstacles on the competition surface. An incorrect assumption was that the teams that performed well in the qualifying round would also be the teams that would advance far in the competition. While this held true for a few teams, there were some teams ranked high after qualifying that, for various reasons, did not make it very far in the final competition. There were also teams that performed unexpectedly well during the final competition who, after the qualifying round, did not appear to be a threat. ~~These factors all contributed to the excitement and intensity of the Mission to Mars competition.~~

Did these assumptions influence your design? If you had gotten them right, would your design have changed? How?

Judging results?

V. Conclusions

This report discussed the performance of the robot JEB2 that was built for the MCHE 201 final project, the Mission to Mars robot competition. The competition presented a number of tasks the robot was required to complete, each awarding assigned point values to the team. Multiple design tools such as a house of quality, specification sheet, and function tree were initially used to get a better overall understanding of the problem at hand. These tools made it clear which customer requirements were of greatest significance in order to build a successful robot. After developing three conceptual design options, an evaluation matrix was constructed to concisely compare the design options against each other. After scoring each design on how well it satisfied the customer requirements presented in the house of quality the design using wheels to move, which would later develop into JEB2, was selected. The simplicity, consistency, and lack of room for error that this design possessed all proved to be crucial characteristics of a robot whose purpose was to be successful in the Mission to Mars competition. Though all did not go according to plan during the competition, Team B2's JEB2 placed seventh out of the twenty-four competing teams. The "Design Performance Evaluation" section of the report broke down the occurrences of the competition and highlighted JEB2's weak points and what could be done to improve upon these.

capitalize

Avoid chronological structure.

VI. References

1. http://crawlab.org/classes/MCHE201_Sp17/Projects/MCHE201_FinalProject_Spring2017.pdf

You don't need this border.

Why so blurry?

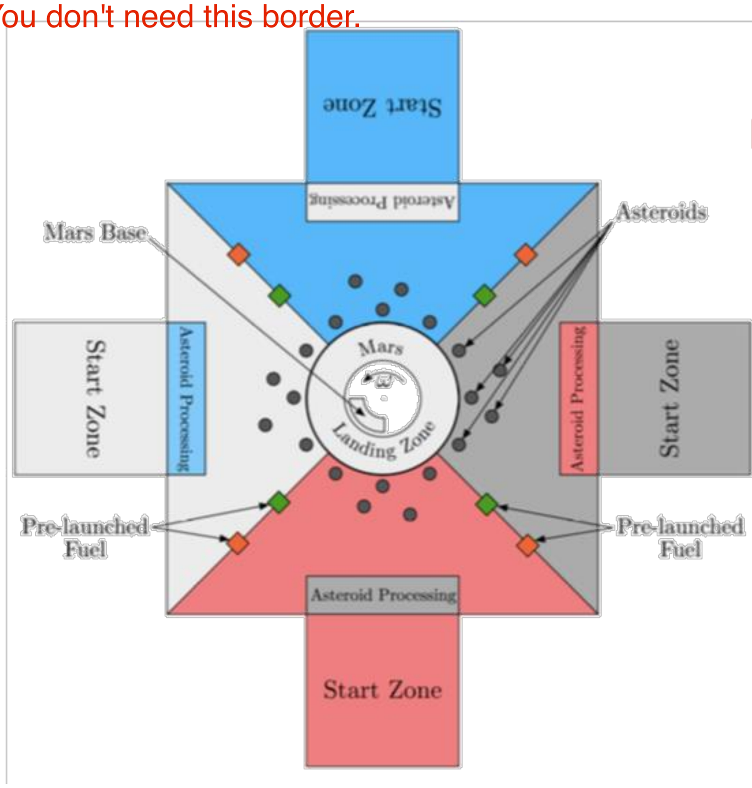
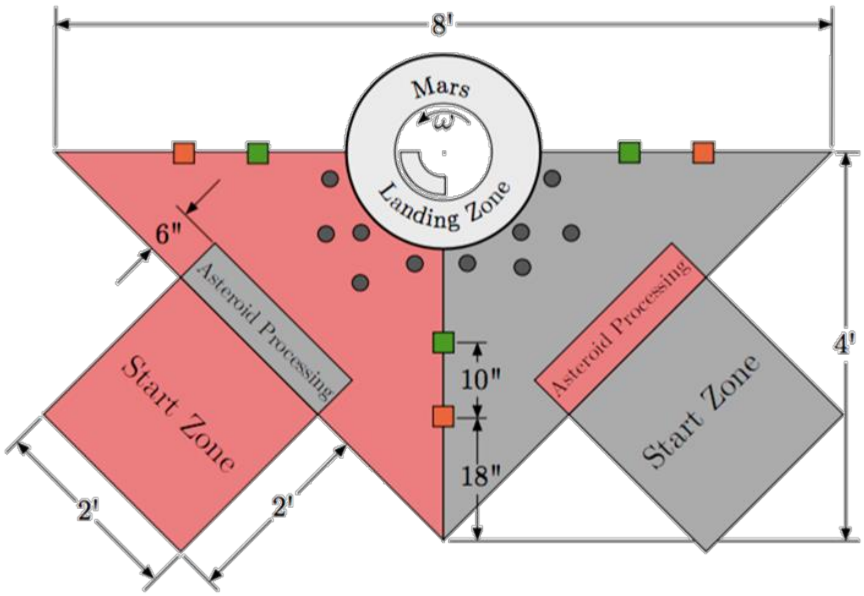


Figure 1: Track Layout [1]



Why so blurry?

Figure 2: Track Dimensions [1]

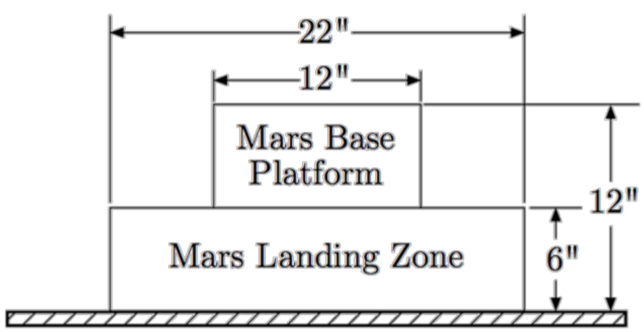


Figure 3: Landing Zone Dimensions [1]

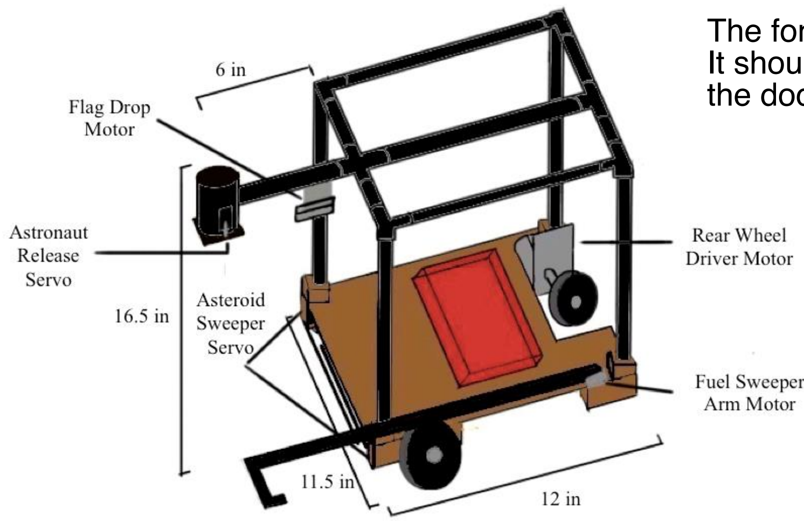


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Figure 4: Chosen Design

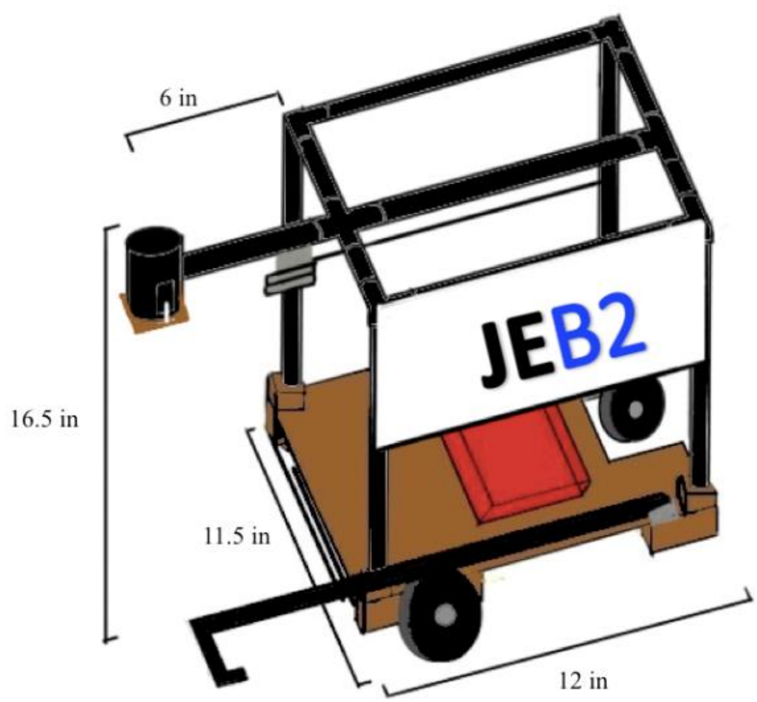
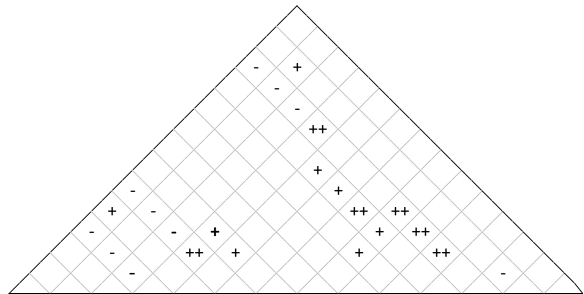


Figure 5: JEB2

Expand

Table 1: House of Quality



Importance	Customer Requirements \ Engineering Characteristics	Length of Robot	Width of Robot	Height of Robot	Weight of Robot	Travel Distance	Travel Speed	Total Operation Time	Setup Time	Cleanup Time	Reset Time	Reliability of Codes (Measured how?)	Number of Materials	Arm Reach Distance	
	Direction of Improvement	X	X	X	▼	X	X	X	▼	▼	▼	X	▼	X	
10	Max of 12 Inches Long	◉			▣	▣	△						▣		
10	Max of 24 Inches Wide		◉		▣		△						▣	▣	
10	Max of 18 Inches Tall			◉	▣	▣							▣		
6	Cheap Final Design Cost	△	△	△	△								◉	△	
10	Operate Autonomously					▣			▣	▣	▣			▣	
10	Operate for no more than 30 seconds					▣	◉	◉				◉			
10	Use only 1 Sparkfun RedBoard								▣		▣	◉	△		
7	High Stability	◉	◉	◉	◉		▣		△				◉	▣	
9	Transport 5 Astronauts to Mars Base	▣		◉		◉	△	◉				◉	△		
7	Clear Asteroids out of Zone		▣					◉				◉	△	◉	
6	Plant Flag in Mars Landing Zone	◉		◉		◉	△	◉				◉	△		
10	Quick Setup Time								◉		▣		▣		
10	Quick Clean up Time									◉	▣		▣		
10	Avoid Disqualifications	◉	◉	◉				◉	◉	◉	◉				
5	Meets Competition Safety Regulations						△					▣	▣		
8	Retrieve Pre-Launched Fuel		▣			◉		◉				◉	▣	◉	
9	120V Power Source						▣					◉			
8	Travel Forward and Backward					▣	▣	◉				◉	▣		
	Absolute Importance	330	294	384	159	351	202	522	247	210	210	618	362	222	= 4111
	Relative Importance (%)	8.03	7.15	9.34	3.87	8.54	4.91	12.7	6.01	5.11	5.11	15.0	8.81	5.40	

Engr. Char should be solution neutral.

Key of Symbols	
◉	Strong
▣	Medium
△	Weak
▲	Maximize
▼	Minimize
x	Target
++	Strong Positive
+	Positive
-	Negative
--	Strong Negative

Table 2 Specification Sheet

		Specification for: Team B2 Robot	**Issued:**	**3/17/2017**
			Page 1 of 1	
Changes	**D/W**	**Requirements**	**Responsibility**	**Source**
		Design Autonomous Robot for Final Competition		
		Geometry		
	D	Maximum Length = 12 inches Length <= 12"	Team B2	Competition Rules
	D	Maximum Width = 24 inches	Team B2	Competition Rules
	D	Maximum Height = 18 inches	Team B2	Competition Rules
	W	10" Max Length	Team B2	Team B2
	W	22" Max Width	Team B2	Team B2
	W	16" Max Height	Team B2	Team B2
		Kinematics		
	W	Able to Travel 2.83 feet forward	Team B2	Team B2
	W	Able to Travel 2.83 feet backwards	Team B2	Team B2
	W	Travels no Less than 0.5mph	Team B2	Team B2
		Disqualifications		
	D	No Foul Language	Team B2	Competition Rules
	D	Dimensions (12"x24"x18")	Team B2	Competition Rules
	D	Fit in 2' x 2' Start Zone	Team B2	Competition Rules
	D	Max Competition Time 30 seconds	Team B2	Competition Rules
		Energy		
	D	Powered by Electric Outlet	Team B2	Competition Rules
	W	Uses Gravitational Energy	Team B2	Team B2
		Signals		
	D	Reads Arduino Code Numerical target?	Team B2	Competition Rules
	D	Turns on Automatically from Signal	Team B2	Competition Rules
	D	Turns off Automatically After 30 seconds	Team B2	Competition Rules
		Materials		
	W	Stable Base Numerical target?	Team B2	Team B2
	W	Rigid Frame Numerical target?	Team B2	Team B2
	D	No more than 2 DC Motors	Team B2	Team B2
	D	Only 1 Stepper Motor	Team B2	Competition Rules
	D	Only 3 Servo Motors	Team B2	Competition Rules
	D	1 Sparkfun RedBoard	Team B2	Competition Rules

Table 2: Specification Sheet (Continued)

		Safety		
	D	No Explosive / Flammable Materials	Team B2	Competition Rules
	W	No Exposed Conducting Wires	Team B2	Team B2
	D	Does not Cause any Damage to Track or Bystanders	Team B2	Competition Rules
		Assembly		
	D	Max Setup Time 3 minutes and 45 seconds	Team B2	Competition Rules
	D	Max Cleanup Time 2 minutes and 30 seconds	Team B2	Competition Rules
	D	Total Round Time = 7 minutes	Team B2	Competition Rules
		Operation		
	W	Transport Astronauts and Flag 2.83 ft to Landing Zone	Team B2	Team B2
	W	Clear all 5 Asteroids out of Team Zone	Team B2	Team B2
	W	Collect at Least 1 Pre-Launched Fuel	Team B2	Team B2
	W	Return to 2' x 2' Start Zone	Team B2	Team B2
	W	Complete All Tasks in 30 seconds	Team B2	Team B2
	D	Shut Off After 30 Seconds	Team B2	Competition Rules
		Costs		
	D	Max Total Cost of $100	Team B2	Competition Rules
	W	Total Cost Less Than $50	Team B2	Team B2
		Schedules		
	D	Have First Prototype Ready for Preliminary Competition (03/23)	Team B2	Competition Rules
	D	Have Second Prototype Ready for Qualifying Round (04/04)	Team B2	Competition Rules
	D	Have Final Model Ready for Final Competition (04/11)	Team B2	Competition Rules

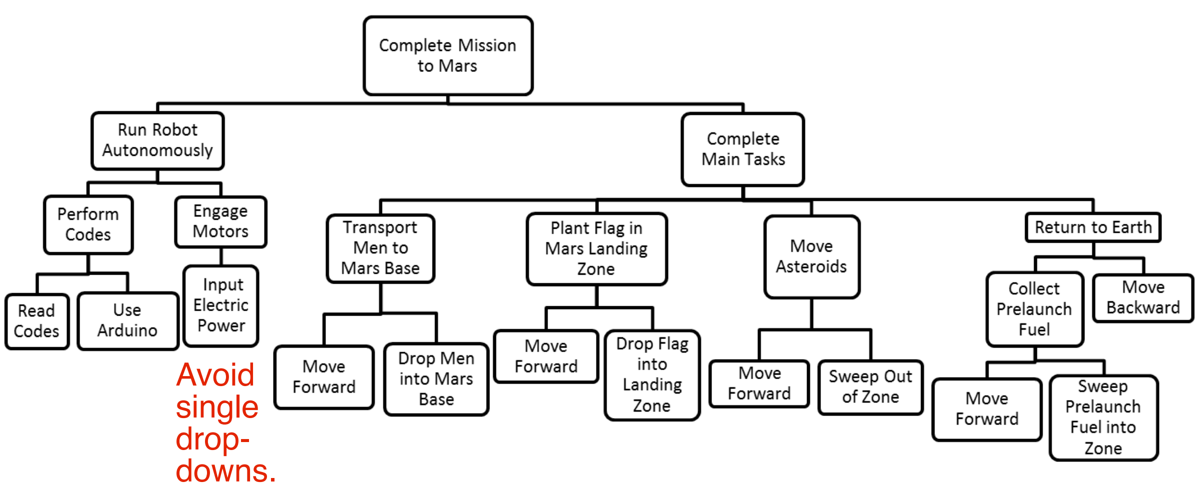


Figure 6: Function Tree

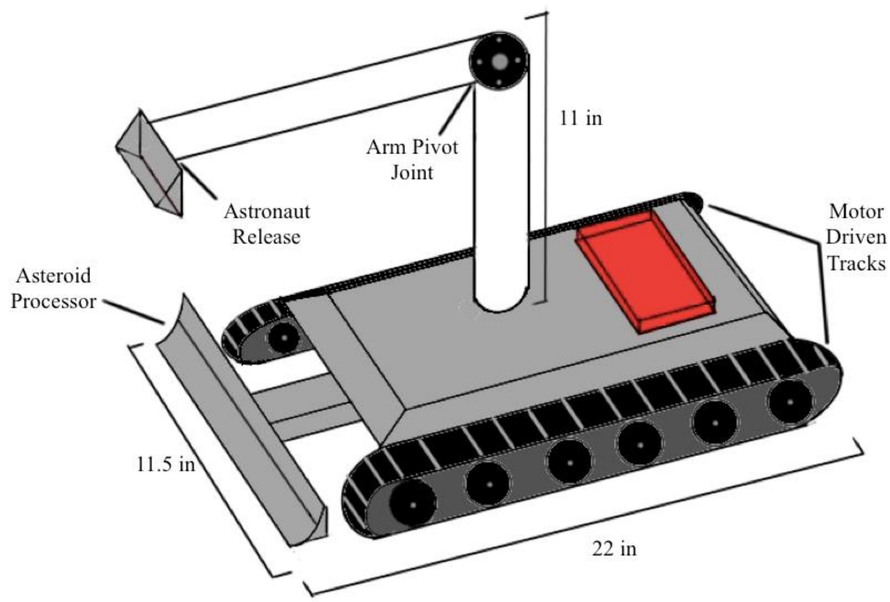


Figure 7: Tank Design

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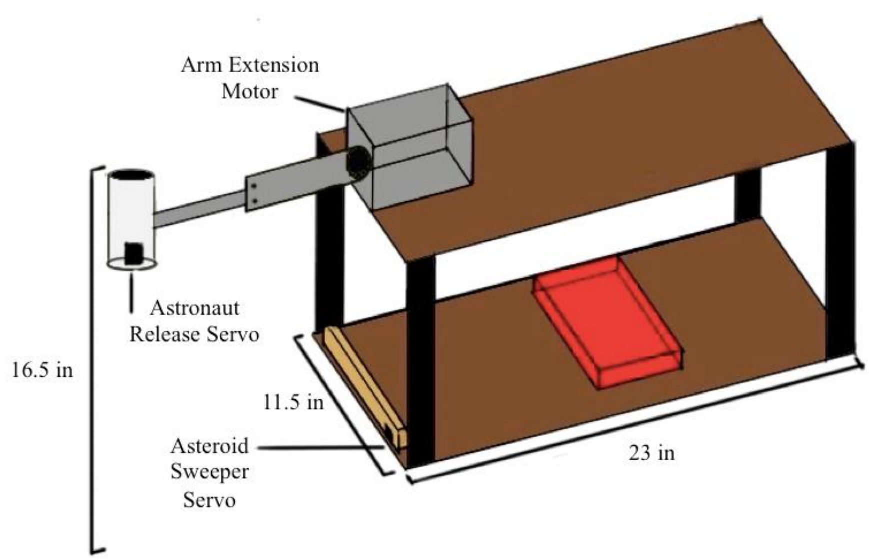


Figure 8: Stationary Design

Table 3: Evaluation Matrix

Move above legend too.

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

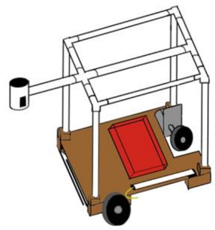
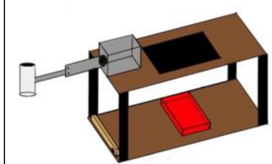
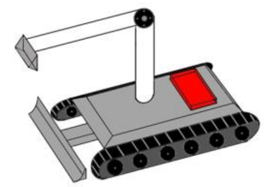
Importanace	Customer Requirements			
10	Max of 12 Inches Wide	9	8	8
10	Max of 24 Inches Long	9	8	8
10	Max of 18 Inches Tall	7	8	7
4	Low Final Design Cost	8	8	8
9	Operate for No More Than 30 Seconds	10	10	10
7	High Stability	9	10	9
10	Transport 5 Astronauts to Mars Base	10	10	9
10	Clear Asteroids out of Zone	7	6	6
10	Mine Asteroids in Processing Zone	1	1	1
10	Plant Flag in Mars Landing Zone	10	10	9
8	Quick Set-up Time	8	8	8
7	Quick Clean-up Time	8	8	8
10	Avoid Disqualifications	9	9	8
9	Meets Competiton Safety Regulations	9	9	9
10	Retrieve Pre-Launched Fuel	6	5	6
8	Travel Forward	10	0	10
8	Travel Backward	10	0	10
	Total	1226	1043	1166
	Relative Total = Total/Number of Criteria	0.72	0.61	0.69

Table 4 Price List

Team B2 Price List	
Item	Estimated Price
Miscellaneous Wood	$20
PVC Pipes	$15
Servo Wiring Extension	$6
Black Spray Paint	$3
Gorilla Tape	$9
Office Chair Wheels	$9
Miscellaneous Nuts and Bolts	$5
Zip Ties	$4

Total?