TEDDY BEAR WHEEL CHAIR DESIGN ENGINEERING FINAL REPORT

Team 104-07, Saudi Arabia

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The authors take shared credit and responsibility for the content within this report.

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1. TBWC Design Summary

1.1. Introduction

Our team of 5 designed and built a teddy bear wheel chair representing Saudi Arabia that autonomously carried out most of the tasks outlined in the 2018 Teddy Bear Wheelchair (TBWC) Football World Cup Skills Competition. The chassis of our robot contains 3 wheels and is made able to move by a pulley system using elastics connected to the motor. The robot sports a long catapult arm which was designed to lob the game ball over the wall and into the net. The same arm is also used to carry the ball for the ramp dribble challenge. Each individual part used in the final construction of the robot was recreated on the computer program Solidworks, which was then used to create a virtual assembly of the robot. Included in this section of the report are PDF drawings of the Solidworks assembly of our robot as well as photos. Both display the top, side, front, and isometric views. In addition, this section also contains a Solidworks based exploded view of our vehicle's complete design, the bill of materials, electrical drawings, and the Arduino code.

1.2. Pictures

Image 1.2.1: Top View

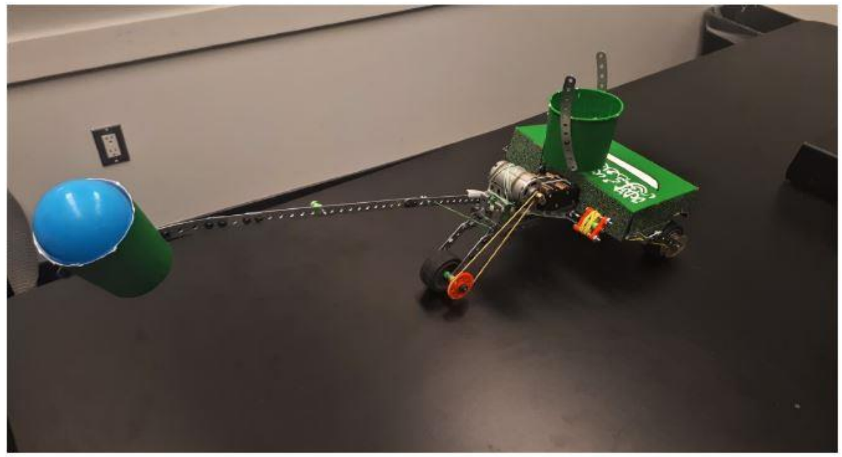


Image 1.2.2: Isometric View

Image 1.2.3: Front View

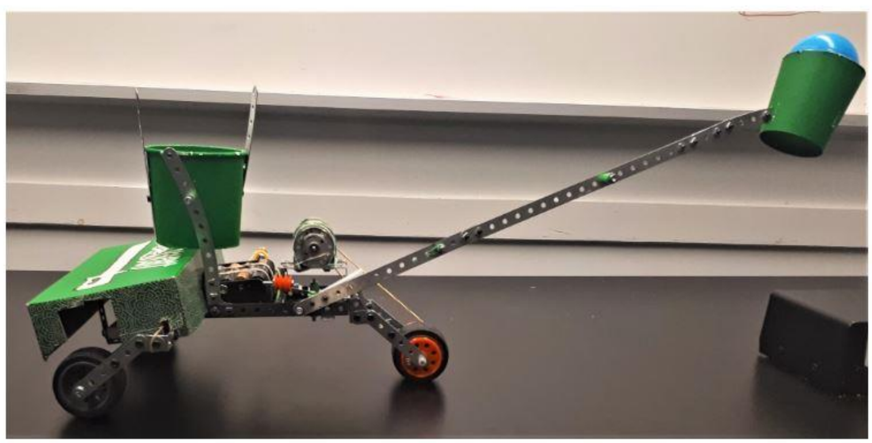
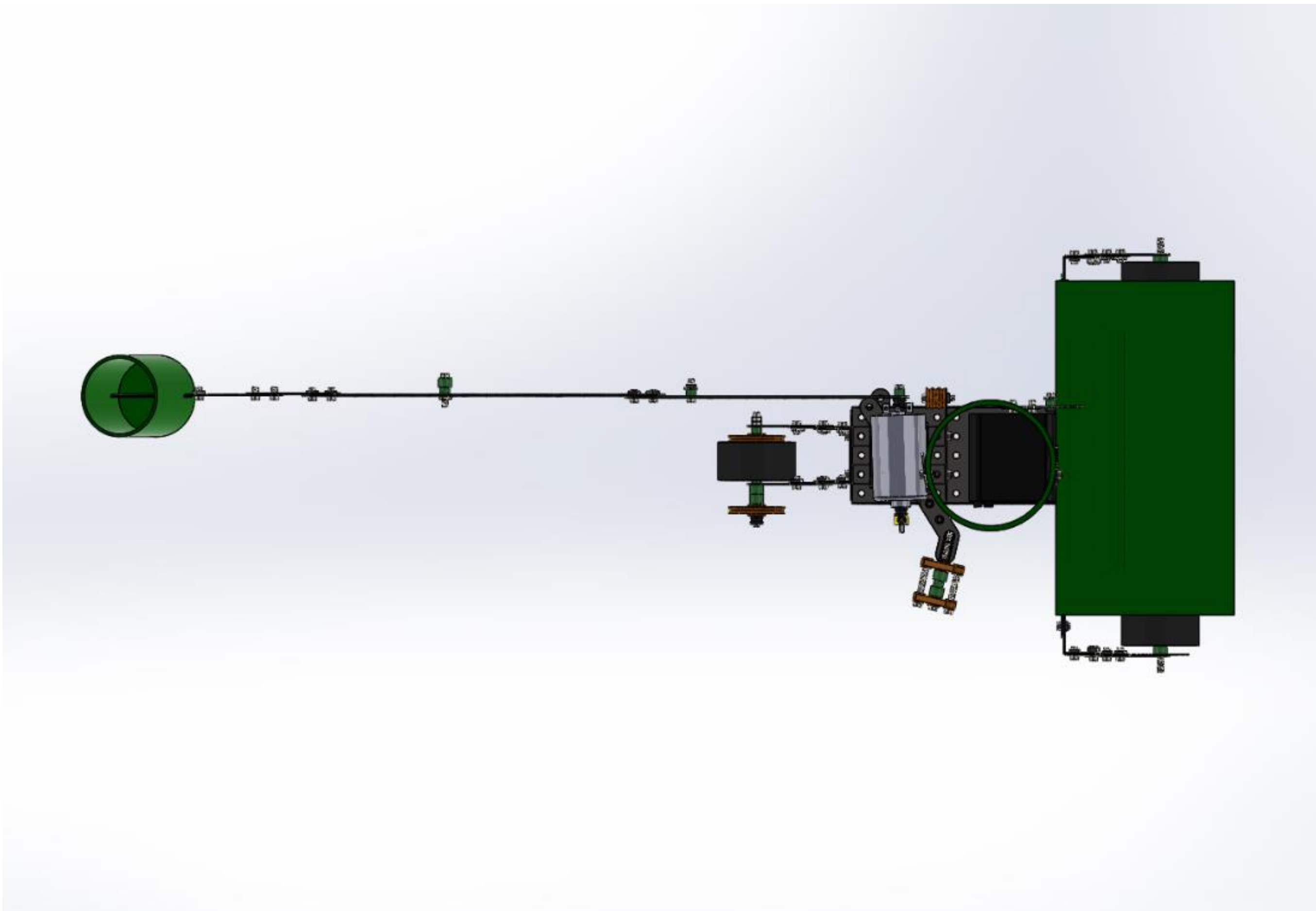
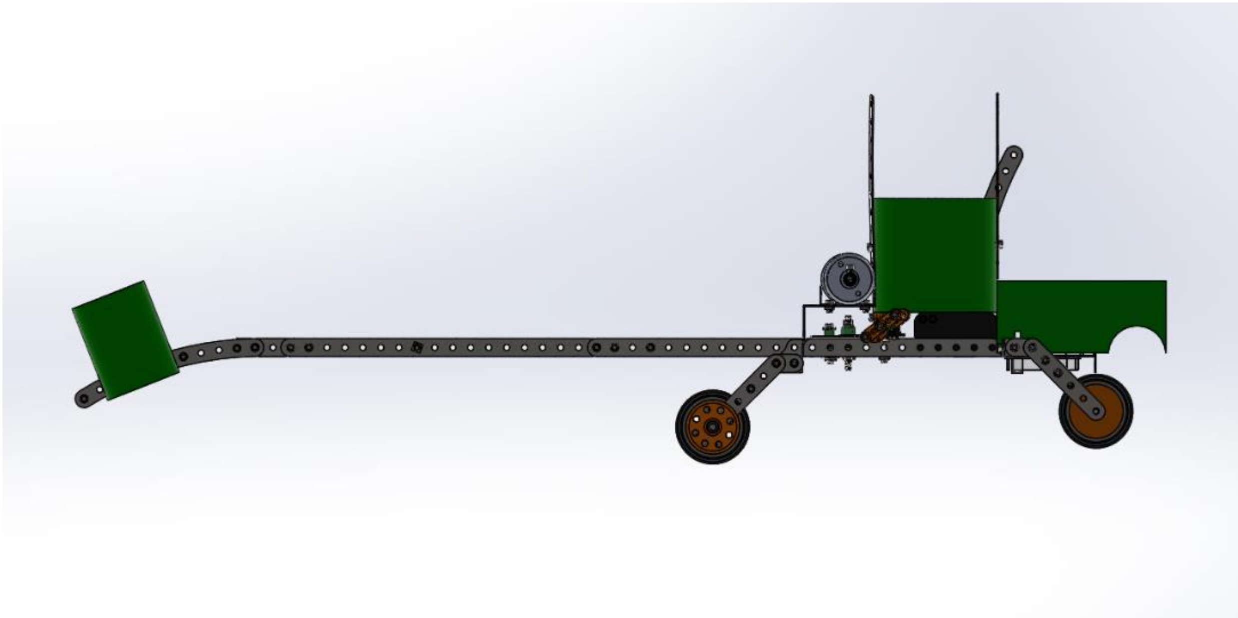


Image 1.2.4: Right Side View

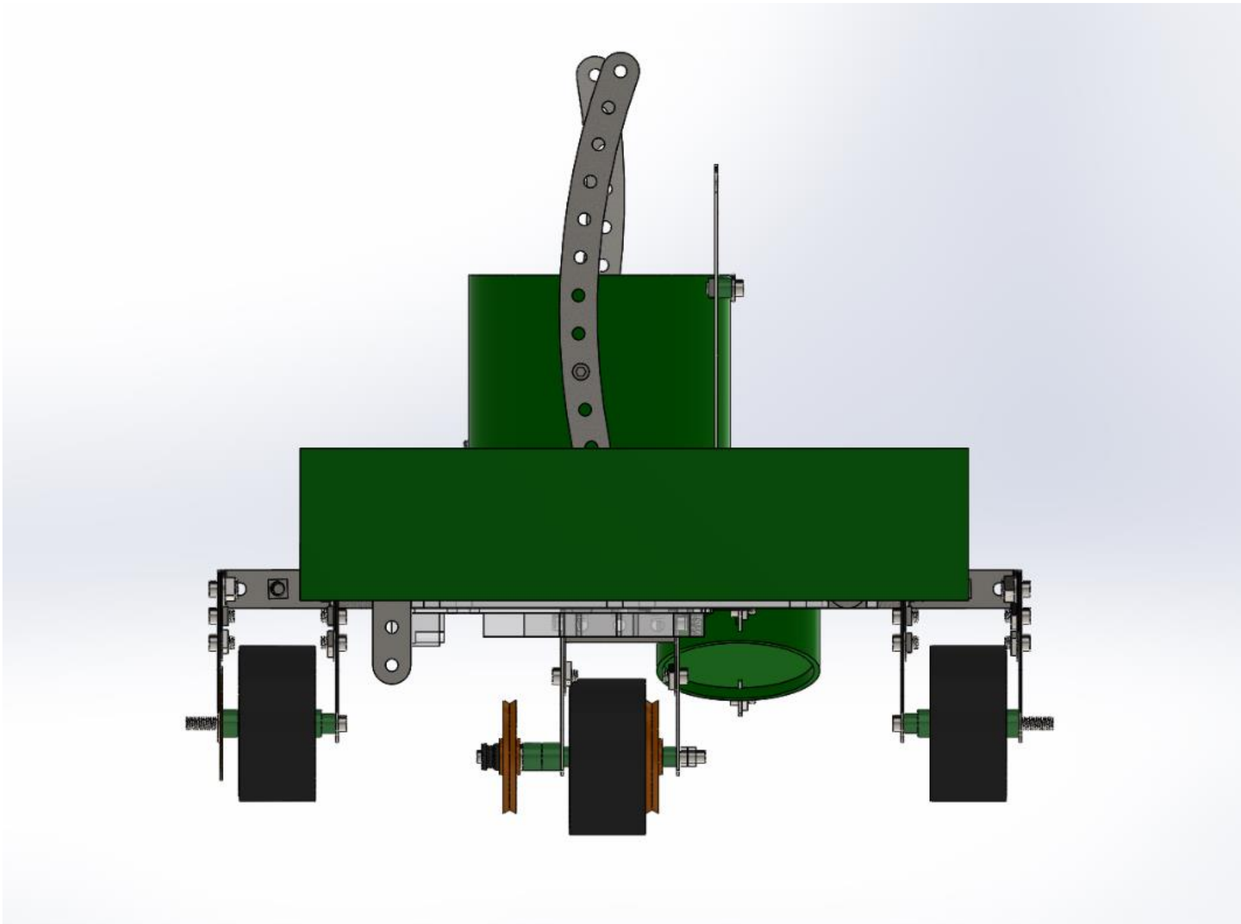
1.3. Technical Views (2D SolidWorks)



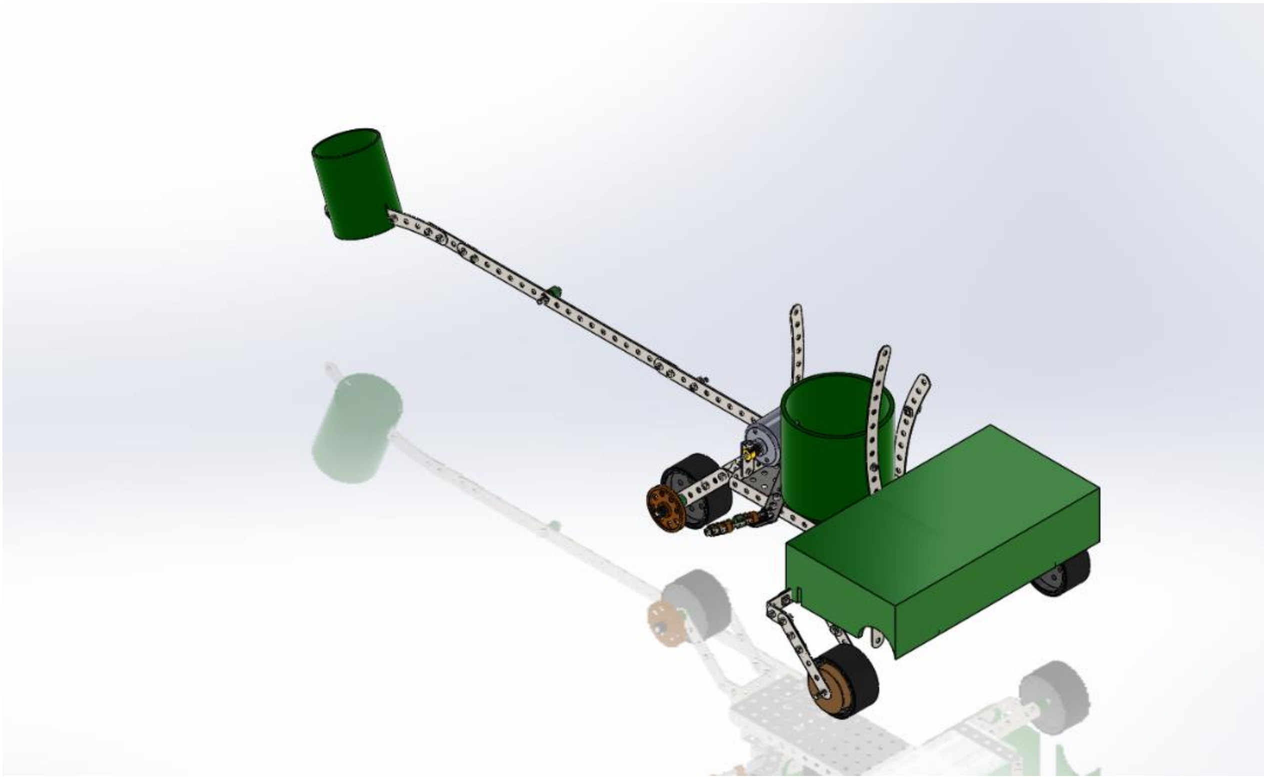
1.3.1 TOP VIEW



1.3.2 SIDE VIEW

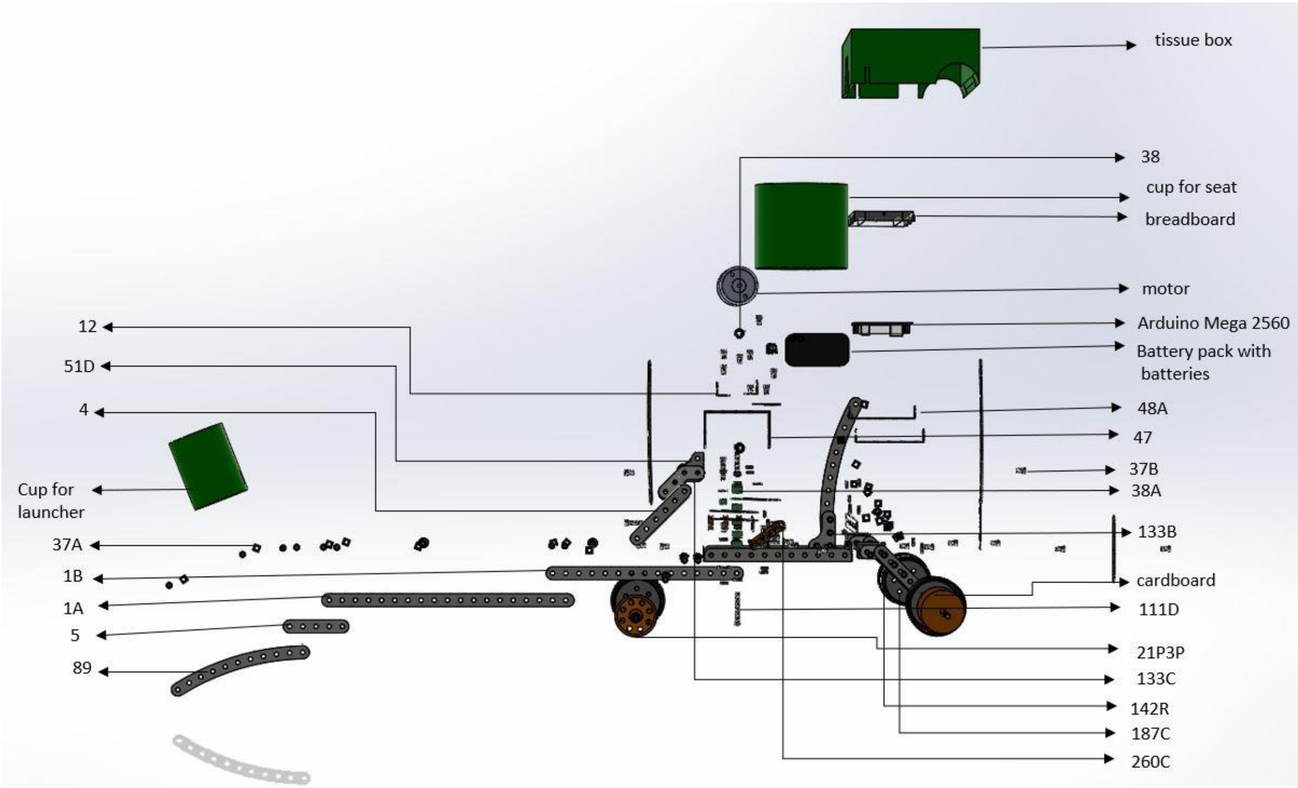


1.3.3 FRONT VIEW

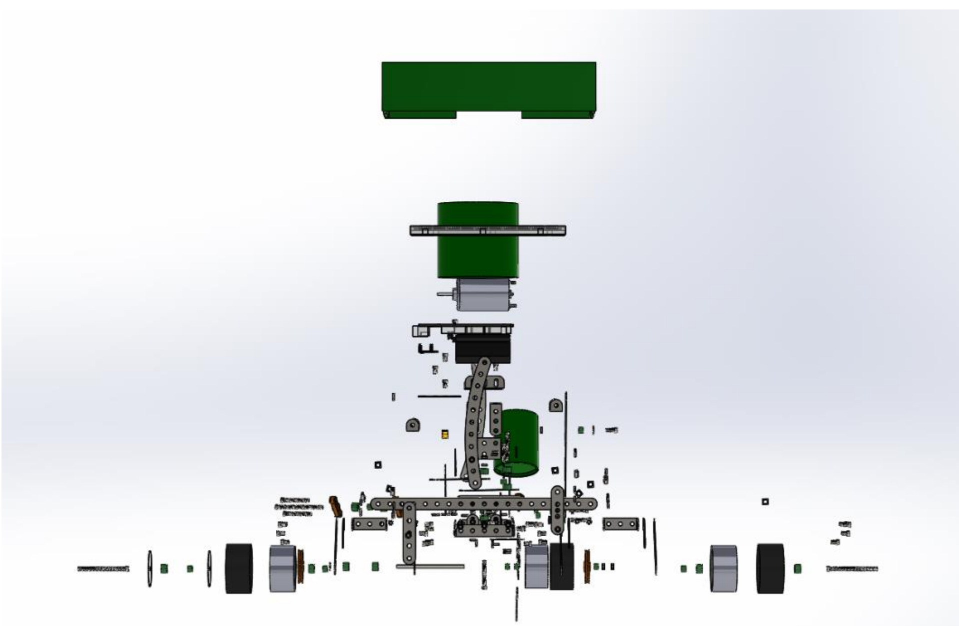


1.3.4 ISOMETRIC VIEW

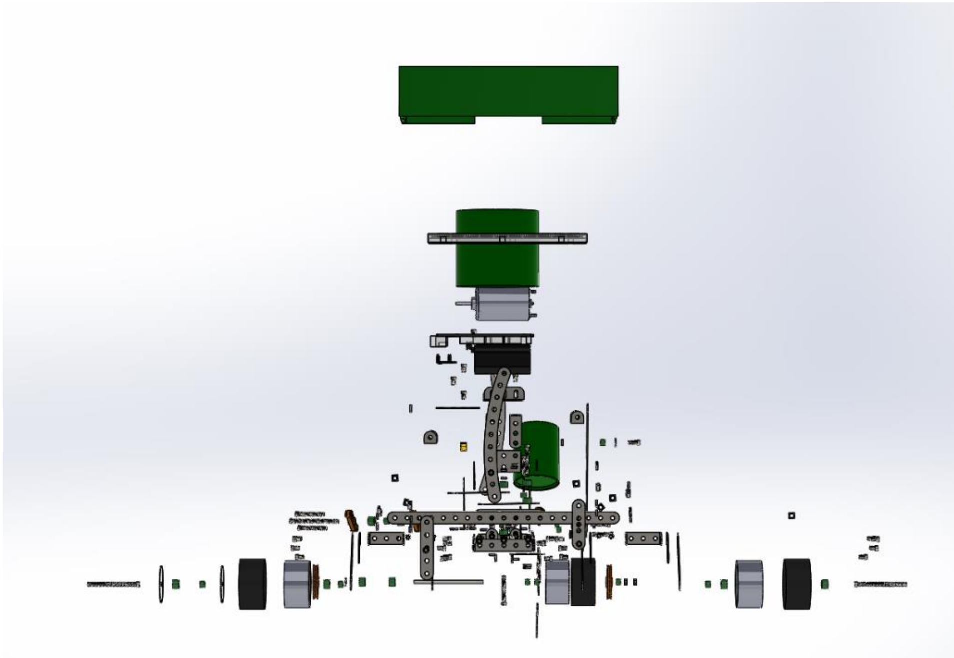
1.4. Exploded Views



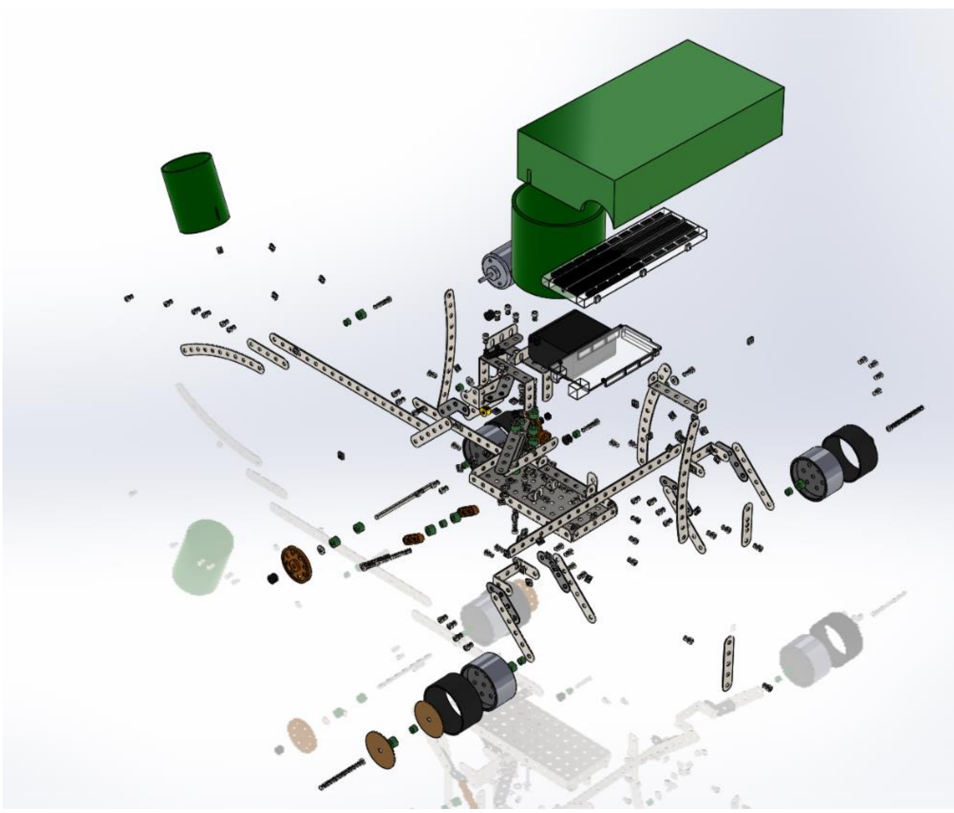
1.4.1 Labelled Side View



1.4.2 Back View



1.4.3 Front View



1.4.4 Isometric View

1.5. Bill of Materials

1.5.1 School of Engineering Supplies:

Part	**Amount Used**	**Material**	**Description**
52	1	Zinc	Flanged Plate 11x5 hole
1a	2	Zinc	Standard 19 hole strip
37b	64	Zinc	Cheesehead Bolt ¼"
37a	55	Zinc	Hexagonal Nut
37h	6	Zinc	Square Lock Nut
46a	2	Zinc	Double Angle Strip 2x3x2
133c	7	Zinc	Obtuse Corner Bracket 3x2
4	10	Zinc	Standard 6 hole strip
48a	2	Zinc	Double Angle Strip 1x5x1
Motor	1	steel	DC – Mabuchi RS-55PH-3255
Arduino Mega 2560	1	PCB	
38a	11	Plastic	Large Washer
38b	12	Plastic	Small Washer
187c	3	Plastic	Road Wheel Centre 1 ¾" Geared
51d	1	Zinc	Corner Flanged Plate 3x2 Hole
317	1	Zinc	Triflat Axle 2"
21p3p	2	Plastic	1 ½" Pully Triflat
38	5	Zinc	Washer
23c	4	Rubber	Pulley Collar 3/8"
59b	1	Brass	Collar 3 Holes
1b	1	Zinc	Standard Strip 15 Hole
6a	4	Zinc	Standard Strip 3 Hole
89	4	Zinc	Curved Strip 11
47	2	Zinc	Double Angle Strip 3x5x3
12	2	Zinc	Angle Bracket 1x1
111	4	Zinc	Cheesehead Bolt ¾"
111d	4	Zinc	Cheesehead Bolt 1 1/8"
9f	2	Zinc	Angle Girder 3 Hole
111a	1	Zinc	Cheesehead Bolt ½"
23b	3	Zinc	½" Pulley without Boss
133b	1	Zinc	Corner Bracket 3x2
6	1	Zinc	Plate 5 holes
59	1	Zinc	Collar
Battery Pack	1	Plastic	
5	2	Zinc	Plate 5 hole linear
142r	3	Zinc	Tyre 1 ¾" Low Profile
260a	1	Zinc	Suspension Mounting Bracket
260c	2	Plastic	Narrow Plastic Spacer
breadboard	1	Plastic/Various	
Batteries	8	Alkaline batteries	

1.5.2 Added Supplies:

Part	**Amount Used**	**Material**	**Description/Cost**
2 inch screws	3	steel	$3.50
rope	2 feet	nylon	$7.00
Tissue box	1	cardboard	$2.50
Coffee cups	2	cardboard	Used for seat and launcher $3.50
elastics	10	rubber	$1.25
Meccano 133c	1	plastic	Made from plastic copying the actual 133c Meccano piece (Obtuse Corner Bracket) No cost
Batteries	8	Alkaline batteries	$5.00

1.6. Electrical Drawings

The following is a list of the components used in our motor circuit and their respective values:

NOTE: since we only used one motor, C_{ENB} and R_{ENB} were not used in our circuit.

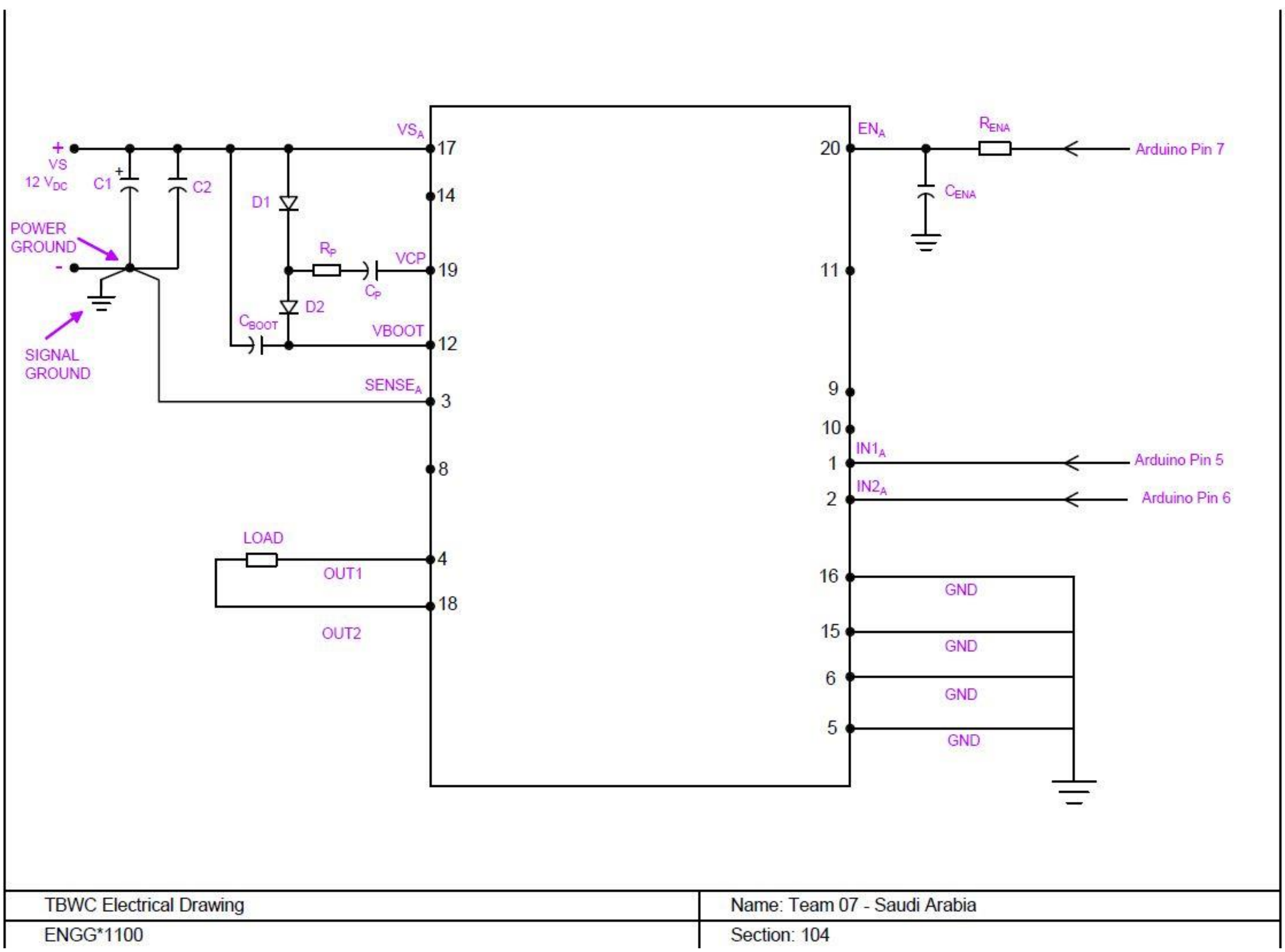
1.6.1 component list

C_1	100uF
C_2	100nF
C_{BOOT}	220nF
C_P	10nF
C_{ENA}	5.6nF
C_{ENB}	5.6nF

D_1	1N4148
D_2	1N4148
R_{ENA}	100kΩ
R_{ENB}	100kΩ
R_P	100Ω

Here is a photo of our circuit, created in AutoCAD Electrical:

1.6.2



1.7. Arduino Codes

The code we ran was a slight variation off the MotorControl_BaseCode file given in lab. Modifications made include adjusting the time delays in order to traverse the correct distance, and adding to the loop to allow forward and backward driving:

<u>1.7.1 Dribble Code:</u>

ENGG1100F18Team07DribbleCode

```
void setup() {
  // initialize digital pins 5,6,7 as outputs.
  //5 - Pink - IN1
  //6 - Yellow -IN2
  //7 - Blue - Enable
pinMode (5, OUTPUT);
pinMode (6, OUTPUT);
pinMode (7, OUTPUT);
}

void loop() {

  digitalWrite(5, HIGH); //Motor ON Output
  digitalWrite(6, LOW);
  digitalWrite(7, HIGH);
  delay(8600);
  digitalWrite(7, LOW);  //Motor OFF Output
  delay(400);

  digitalWrite(5, LOW); //Motor ON Output
  digitalWrite(6, HIGH);
  digitalWrite(7, HIGH);
  delay(11000);
  digitalWrite(7, LOW);  //Motor OFF Output
  delay(1000);

}
```

1.7.2 Freekick Code:

ENGG1100F18Team07LauncherCode

```
void setup() {
  // initialize digital pins 5,6,7 as outputs.
  //5 - Pink - IN1
  //6 - Yellow -IN2
  //7 - Blue - Enable
pinMode (5, OUTPUT);
pinMode (6, OUTPUT);
pinMode (7, OUTPUT);
}

void loop() {

  digitalWrite(5, HIGH); //Motor ON Output
  digitalWrite(6, LOW);
  digitalWrite(7, HIGH);
  delay(4600);
  digitalWrite(7, LOW);  //Motor OFF Output
  delay(2000);

}
```

2. Performance Summary

2.1 Complete Performance

This competition went well for us. We passed the mass test and the safety test perfectly. We did well in the ramp dribble course however we did not complete the course in the required time. For the Soccer Free-Kick course we also did alright. Our launcher launched the ball each time however it did not always go over the wall and never scored in the net. On aesthetics we also did well, and our life cycle calculations were low.

Table 2.1 - Performance Summary Table

Item	**Performance**	**Notes**
Ramp Dribble Course Times(s)	18.1 Seconds	We only went once for this event because we knew we were not going to be able to take off the 6 seconds required to get more points than we already did for this event.
Soccer Free-Kick (Goals scored, Points)	0 Goals, 20 Points	The robot launched the ball all three times. However, the ball only made it over the wall one time. It never scored into the net.
Mass Measured (g)	1190 Grams	We were very careful throughout our whole design process to make sure that we would be under the weight limit.
Aesthetics	9.29 Points	We used all green wires, spacers, and cardboard pieces along with having the flag painted on the front. As a team we thought we could have done a little more when it came to this aspect, however it seemed to still go over well.
Safety	Pass	We passed the tipping test and the upside-down test all perfectly with no problems. The bear fell out while upside-down.
Calculated Values		
Mass Calculated (g)	1190 grams	We decided from the very beginning that we didn’t want to have two motors so that we would be able to be light enough to be under the mass limit.

Centre of Mass Location (x,y,z in mm)	Xcg = 140.848169 Ycg = 187.26411 Zcg = 71.10947	The center of mass was calculated for each major axis of the robot, assuming one of the wheels was placed at the origin
Greenhouse Gas Emission (kg CO2e)	3.858236425	We were able to keep this number low as we were careful not to use many batteries and we did not use Meccano pieces that we did not 100% require
Water cyanide contamination (kg CN)	4.52e-4	This number is low because we were careful not to use unnecessary Meccano pieces which would make this number higher
Battery consumption (Number of batteries used in the whole process)	16	We were very careful throughout all of our design steps to make sure to limit the amount of batteries we needed

3. Reflections

3.1 Ramp Dribble

This test went well for us. Our robot moved slowly, however it drove the correct distance forward and backward and was able to go over the ramp successfully both ways. We got full marks for completing this event however we got zero extra points for completing it in a specific time frame.

At the beginning of the project, we had a hard time getting the wheels to move, which could have had a large negative impact in this event. We tried many different techniques to try and get the rear wheels to move together around their axle. In the end we used only one back wheel and tightened it around a shorter axel as much as possible by stuffing elastic band pieces around the Meccano parts that attached the wheel to the motor.

During the practice event a few weeks ago, our robot went very fast and completed the course in ~10 seconds. We made minor changes to the TBWC but we did not add or remove anything that would have significantly affected the total mass. However, when we were testing the day before the competition, it was moving very slowly. We tried modifying the code and using new batteries, but neither made the robot move any faster. After these feeble attempts, we decided collectively that we would prefer to lose the 6 points for moving slowly instead of tearing our robot apart to see what we had to fix for it to move faster and potentially make the problem worse.

It is unclear what we could have done to solve this problem since this issue only appeared the day before our competition.

We designed our robot to have its wheels spread apart widely to maximize stability going over the ramp. We also designed the wheels to be high enough so that our launcher would not drag on the ground going over the ramp, but not so high that it would become unstable. In these designs we were successful and did not have any problems in competition.

3.2 Free-Kick

This test went better for us then we expected. During the design, we came across a problem when it came to trigger the launcher. We really wanted to only use one motor so that we could get the full points for the mass test however this came with so many challenges. By competition day, we had designed and attempted to use three completely different launchers each with a different trigger mechanism, and within these three designs there were many iterations made. The night before our competition, we decided our current launcher was not going to work. We decided to design, create, and perfect a new launcher with only hours before evaluation. We introduced new materials and a new triggering method, and we tried it many times each time analyzing what went wrong the previous time and what minor adjustment we could make to get it to work consistently. When we finally finished adjusting the new launcher mechanism it was working 80 percent of the time. We decided as a group that this was the best mechanism we were going to get since at that point we were very close to the competition deadline and we would prefer for it to work 80 percent of the time instead of having no launcher and it not working at all. When we had to present our launcher, it launched all three times (which we were all very excited about) however it only went over the wall once and it narrowly missed the net this time.

This was a difficult problem to solve since we had invested so much time and effort into perfecting the old trigger and only spent one night building the trigger we used in competition. After we decided using the old trigger would not be possible, we all worked extremely hard to come up with a new idea that would work. If we had another week (or decided to change our launcher a week earlier), we would have been able to optimize this new design and it most likely would have shot perfectly into the net every time.

A second issue that we ran into quite early into this project was our launcher did not really "launch the ball". The design we used was a cup attached to a Meccano arm that threw the ball like a catapult. Instead of figuring out how to launch with elegant projectile motion, we came up with a simpler strategy to employ a long arm that reached higher than the wall, travel right up to the wall and simply dump the ball over towards the net. This solution had advantages and disadvantages however in the end it worked out alright considering all the other problems we had with the launcher mechanism.

3.3 Mass Reflection

The mass test went very well for us. We were just under the weight limit which meant we got the full 30 points for this portion. We were able to achieve this light weight by using one motor instead of two.

Using only one motor caused us many problems when figuring out the triggering mechanism for the launcher. However, in the end it was worth it because we were able to have the weight light enough to get full points and still have a launching mechanism that was mostly functional and gave us decent results. If we had sacrificed the weight and added a second motor, we would have been way overweight and only gotten a few more points in the launching challenge even if we got all the goals in the net.

Our group knew that having only one motor was going to be extremely challenging however we decided that we were willing to put in the time and effort to accomplish the challenge.

We were also very careful when we rebuilt our robot shortly after the prototype testing. We made sure we only used Meccano that we absolutely needed and always tried to use lighter options when possible. We were very aware of everything we put on the robot and tried to keep parts to a minimum while still making sure we had everything we need to be functional and remain competitive.

3.4 Aesthetics Reflection

Our aesthetics went over a lot better than we were expecting. We did not put as much time as we wanted into the aesthetics because there were so many issues with the robot, however we still got 9.29 out of 10, which we are all very proud of. In our very first meeting we talked about how we wanted the wheel chair to look and we had some amazing ideas that could have made our wheelchair look very 'cool'. We wanted to dress the teddy bear up in traditional Saudi clothes and dress the wheelchair in symbols representing Saudi Arabia such as an eagle and palm trees. We also wanted the teddy bear to be holding a tiny Arabian sword.

Some of these ended up being unrealistic to manage and create, and for others we just ran out of time to pull off such creative ideas. In the end our robot still represented Saudi Arabia well. We tried to get everything to be green. We used green wires for our breadboard, we traded with groups to try and get only green spacers, we pained all the cardboard we ended up using green and we painted the flag on the front of our teddy bear wheel chair. We also used green elastics in as many places as we could. Using the green elastics everywhere ended up being a challenge because we needed specific length, width, and elasticity for different elastics to do their tasks properly so a few of the elastics ultimately could not be green.

We also had to be careful that our aesthetics were not too heavy. We wanted full points for weight, but our aesthetics needed to be effective enough that you could clearly see that we were representing Saudi Arabia. In the end our aesthetics worked out well, but we could have worked a little harder so that we had a more interesting/creative design.

3.5 Safety Reflection

Our final design passed the tipping test with flying colours and allowed our teddy bear friend to escape unscathed in the event of an emergency. Although our *final* design incorporated the proper safety aspects, at various points along the design process we brainstormed/attempted some less than safe ideas.

Of note was our original idea for the launcher trigger. Since we made it our goal to only use one motor right from the beginning, we were plagued throughout the entire process by trying to come up with a smart and simple way to combine 2 functions into the one motor. Originally, we tried to attach an arm onto the motor shaft, right beside and perpendicular to where the elastic which drove the vehicle was nested. The idea was that this trigger arm (which had a hook shape) would spin as the wheelchair advanced, and would bypass a mechanical switch, however once direction reversed, the hook arm would catch on the switch and release our catapult.

In hindsight, we spent an absurd amount of time trying to make this design work because it was not a smart idea due to the intense vibrations produced from the constant contact from the trigger arm against the switch. These vibrations ultimately caused issues related to power supply; vehicle would intermittently lose power and then start moving again, and steering; the trajectory was very hard to predict since the vibrations would actually turn the vehicle. We never tested this sketchy design with a live teddy in fear that he might injure himself beyond that which put him in a wheelchair to begin with, but we spent so long trying to make the idea work safely that we did not decide to change our idea to what we ended up using until the night before the competition. Had we abandoned the loud and shaky trigger a week or two earlier, our final trigger would have been much more finely tuned, and we probably would have scored at least one goal in the free kick competition!

Another way we incorporated safety for the passenger into our design was by way of guard poles attached to the seat. This was an idea we had from the very beginning and it was very simple yet effective since our teddy bear had a smooth ride throughout. The idea was inspired by the pole on merry-go-rounds that children hold onto while riding. While our teddy bear didn’t hold the poles, we attached one in front of him and one behind to stop him from falling out if he leaned in any direction. When flipped upside-down, the poles allowed the teddy to escape from the wheelchair unharmed.

One last notable safety feature we played with (but didn’t end up using) was an elastic suspension system. This was another very simple idea; elastics tied underneath and to the center of the wheelchair base would attach to each wheel assembly, which would be hinged so that they had a range of motion. This would allow a smoother ride for the passenger when the vehicle encountered bumps along the ride. We implemented the idea successfully on one wheel, but adding the hinge made the wheel assembly more complex so we decided that while it was a cool idea and seemed to work fairly well, it wouldn’t change our performance in the competition and wasn’t worth the extra work and maintenance to add more moving parts.

3.6 Life Cycle Analysis Reflection

Our life cycle analysis for the batteries was quite low. This is because we very strategically used our batteries. We had one set of 8 batteries that we used every time we were just trying stuff out and seeing what was going to work or what was not going to work. We could not use these batteries when we tried to accurately program the Arduino because they made the robot move much slower than fresh batteries. We then had a second set of batteries that we ONLY used for the actual test day. We programed the Arduino properly a couple hours before the testing and only ran it once or twice with the new batteries before the competition so that we would not drain them.

For the rest of the materials we used, the CO_2 combined with the CO_2 equivalent was quite high. It was almost double the total from the batteries. The motor added a huge amount, so it was good that we did not use two because that would have had contributed even more. Also, the fact that we were being so careful about mass helped minimize the life cycle impact because if we had miscellaneous pieces that we did not totally need, there would have been even more pieces that we had to account for and would have increased life cycle numbers.

All together we had a low life cycle analysis because we were very careful of the material that we used and tried to be as careful as possible with battery usage.

3.7.1. Team Reflection

As a team, we were able to analyze our weaknesses and improve on most of them. During the week 7 review of team performance, we went over a few things that we needed to improve on. One of these things was limiting the number of mediums used for communication. We successfully implemented this rule by deleting all our different team group chats save for one. Microsoft Teams was chosen as our one and only means of communication (aside from talking in person) as the application was designed to be used specifically for professional teams. Implementing this change resulted in fluent, on-topic conversations as we were able to channel our different topics all on the one application. In addition, using a singular app meant that there was no confusion regarding on which app certain files, folders, and conversations were.

Another thing we improved on was the consistency of our meetings. Before the week 7 evaluation, we had a mixture of weekly and spontaneous meetings. Although the spontaneous meetings were useful, we found that the change in each members' schedule caused more stress. As a result, we ended up having more weekly meetings. This helped reduce stress on individual members, as getting in the routine for meetings at the same time each week made meetings more of an addition to our lifestyle and less of a chore.

Although we proposed to keep an attendance list for each meeting, we found that our time was better spent on other priorities. We still had difficulty with full attendance, but we usually had at least 4 members present. During meetings we got straight to work and stayed on task for almost the entire duration. Even for the meetings that reached 11+ hours in length, we kept it professional and worked hard – completing each of our assigned tasks.

As the weeks went on, we got to know each other better and thus became more comfortable around one another. Often, team members tend to socialize more and work less as they get to know each other better, but we were careful not to fall into this common trap. Instead, we used our growing friendships to our advantage when making changes to the robot. The quiet group members were finding the confidence to voice their opinions and ideas with other members, and inhibitions no longer held us back from telling one-another how we truly felt about ideas. Generally, if an idea was unfavoured, criticism was delivered constructively and alternatives suggested instead of "slamming" down on the idea.

Overall, we had great chemistry right from the first week, and the more we got to know one another, the better we worked. We had no problem recognizing our strengths and using them to our advantage, as well as finding our weaknesses and improving on them.

3.7.2

Original Team Contract:

School of Engineering

Engineering & Design I (ENGG*1100)

Team Contract – Team TBWC 0104-7

1. We will show up to every meeting.
2. If we need to be late or miss a meeting, we will give each other 24 hours' notice (if possible) so that we can reschedule the meeting as necessary.
3. We will all maintain group expectations and will complete our assigned parts for every meeting.
4. We will distribute the workload fairly amongst all team members so that everyone is doing an equal part for the project.
5. We will all submit original work (no plagiarism).
6. We will make all decisions based on majority vote.
7. We will all be friendly and respectful to everyone in our group and listen to everyone's ideas and inputs equally.
8. We will create a schedule together and each do our part to follow it.
9. Someone will take notes during every meeting and then send a picture of the notes in the group chat to keep everyone up to date on what is going on.
10. Team decisions and ideas will be confidential and not shared with people outside of our team.

Please sign below, indicating that you contributed to the creation of this team contract, and understand and agree to adhere to its contents.

Team ID Code: 0104-7

Name	Signature	Date
AMANDA KNIGHT	A. Knight (Signature)	25/10/2018 (Date)
DAVID BRYCE	David Bryce (Signature)	25/10/2018 (Date)
ISABELLA ROHNER-TENSEE	(Signature)	25/10/2018 (Date)
KARAM ABU EL HAIJA	(Signature)	25/10/2018 (Date)
OWEN DOUGLAS	Owen Douglas (Signature)	25/10/2018 (Date)

3.7.3

Week 7 Team Contract Review, Updates and Team Reflection

Overall, our team has been working well together. We have mostly stayed true to our contract, but we found it difficult to completely follow it to a tee. Some rules we had difficulty following were: showing up to all meetings, and giving each other 24 hours notice if missing a meeting. Additionally, we have also had slight problems with communication. Initially, we agreed to solely use Microsoft Teams to communicate outside of meetings, but we started to use multiple applications which simply complicated communication.

New Rules:

We still believe it is important that everyone shows up to scheduled meetings, therefore we are going to keep this rule in the contract. However, to make better use of it, at the start of each meeting we will look at everyone's schedule to determine when our free time coincides. We will also add a clause about excuses for missing a meeting only being valid if the majority of the team agrees. Absences without a valid excuse will be duly noted. Also, we are adding a rule that Microsoft Teams will be the only application used for team communications.

Rational for new Rules:

- Dedicating an amount of time to discuss scheduling of future meetings will help reduce member absences.
- Recording absences will further remind each member that team meetings need to be prioritized and will help monitor each person's contributions. Voting on absence validity will allow everyone to prioritize school work guilt free yet discourage slacking off.
- We looked over all the features on Microsoft Teams and concluded that it will benefit our team more than any other communication applications since it is targeted towards professional applications. Teams is also great for organizing different ideas and data, eg. Chats, documents, pictures, schedule.

3.7.4

Revised Team Contract – Week 7:

School of Engineering

Engineering & Design I (ENGG*1100)

Team Contract – Team TBWC 0104-7

1. We will show up to every meeting.
2. If we need to be late or miss a meeting, we will give each other 24 hours' notice (if possible) so that we can reschedule the meeting as necessary. If we are not able to give 24 hour notice we will inform our teams of the reason why we cannot be at the meeting. If the rest of the team determines this to be an invalid reason then it will be recorded that one missed a meeting for an invalid reason and this will then be discussed in the final team reflection and report.
3. We will all maintain group expectations and will complete our assigned parts for every meeting.
4. We will distribute the workload fairly amongst all team members so that everyone is doing an equal part for the project.
5. We will all submit original work (no plagiarism).
6. We will make all decisions based on majority vote.
7. We will all be friendly and respectful to everyone in our group and listen to everyone's ideas and inputs equally.
8. We will create a schedule together and each do our part to follow it.
9. Someone will take notes during every meeting and then send a picture of the notes in the group chat to keep everyone up to date on what is going on.
10. Team decisions and ideas will be confidential and not shared with people outside of our team.
11. We will only use Microsoft Teams for all communications surrounding meetings, ideas, etc..

Please sign below, indicating that you contributed to the creation of this team contract, and understand and agree to adhere to its contents.

Team ID Code: 0104-7

AMANDA KNIGHT	(Signature)	25/10/2018 (Date)
DAVID BRYCE	(Signature)	25/10/2018 (Date)
ISABELLA ROHNER-TENSEE	(Signature)	25/10/2018 (Date)
KARAM ABU EL HAIJA	(Signature)	25/10/2018 (Date)
OWEN DOUGLAS	(Signature)	25/10/2018 (Date)

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