Senior Design
Critical Design Review
4/10/17

The Mars Rover

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Executive Summary

Last semester, the Mars Rover group received approval to move forward with the design presented in the Preliminary Design Report (PDR). The design provided solutions to problems,as set forth by the client, with the previous Rover design such as:

- The suspension of the rover is made of metal piping, giving it a sleek, modern look.
- The body of the rover has metal braces added to the exterior that not only add support, but hide unsightly weld marks, improving the design.
- The use of motors connecting directly to the wheels and housing instead of gears, lessening the room for error.
- A controller that interfaces with an Arduino was used to allow easy control of rover.
- Store bought tires are fitted on the rover to replace the handmade wheels previously used.

The solutions of the design have increased the aesthetics of the Mars Rover. Testing has shown that the design proposed in the PDR has improved the rover, in both design and function. The new suspension not only improves the looks of the vehicle, but allows for parts to be easily replaced due to its modular design of prefabricated parts. It also allows for wires to be hidden within the pipes. The body is strong enough to hold everything required for a mission, to maintain control of the project and has a clean design. The simplicity of the control system allows for the user to easily pick up the remote controller and use the Rover, assuming the batteries are charged. Through testing of the design and analyzing the results, the team has come up with recommendations for future improvements on the design.

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Introduction

The objective of this this project was to deliver a design for a Mars Rover that focused on aesthetics without sacrificing functionality. Previously a senior design group had delivered a Mars Rover, seen in **Figure 1**, to the client, Dr. Anthony Choi. Dr. Choi found that the previous design lacked aesthetic value.

Figure 1*:* *Previous Design*

The cause of the previous design not meeting the aesthetic standards set by the client was due to the use of aluminum bars and exposed welds, as well as the use plywood for the body, and PVC pipe for the wheels. After analyzing the previous design flaws , in terms of function and aesthetics, a design was constructed that would be more aesthetically oriented while still functioning as a Mars Rover.

Summary of PDR

Last semester a design was chosen for the Mars Rover that would use prefabricated steel pipes as the main suspension component. The design would use sheet metal for the body of the Rover and manufactured stock wheels for movement. The motor housings from the previous design would be repurposed for the new, better looking design. A microcontroller would be added to link the motors to the remote controller, allowing for ease of use. The design met all of the feasibility set forth; reporting a cost under a set budget, maintaining more aesthetic appeal than the previous design, and n function as a Mars Rover design.

The two mechanical engineering students (MAE) on the project would work on the mechanical aspects of the design (suspension, body, wheels, motor housing and bearing housing) while the computer engineering student (ECE) on the project would be responsible for the wiring and controlling of the Rover.

Methods and Work Accomplished

Overall Design

The overall design of the Mars Rover is based on NASA's Rocker-Bogie design. With the goal for a Rover to be remote controlled far from the user, maintenance is typically unlikely. Therefore, to limit the possibility of maintenance or failure in trekking, the Rocker-Bogie Design incorporates as few mechanical components as possible while still functioning as desired.

To make the Rover look visually appealing, hollow piping was used to create a smooth, sleek appearance and hide the internal wiring of the Rover. Containing the wiring inside the Rover to make it an entirely internally operated device also provides protection for the wiring on rough, jarring terrain, which can be seen below in **Figure 2**.

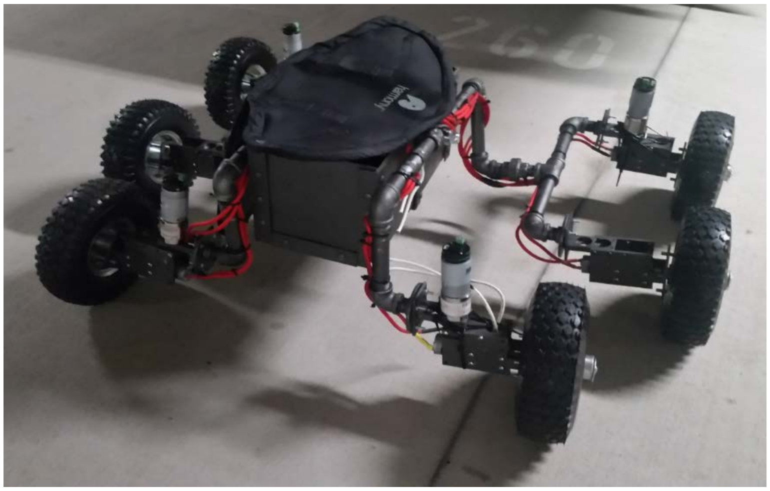

Figure 2: *Fully Assembled Rover*

Focusing on utilizing gravity, the body is ideally located in the exact center of the moving parts of the Rover to maintain balance on movement. The body also is connected to the suspension with a rod allowing it to freely rotate despite movement of the suspension. This assures body contents stay within the body and it stays upright.

The Rover is intended to go over rough terrain. Therefore, manufacturer-made, rubber and large-diameter wheels were purchased. These wheels required attachments be machined to appropriately fit onto the Rover suspension while allowing rotation without any resistance.

A car battery is the power source for the motors' driving movement. The body is left open on the top and reinforced with steel brackets. Due to the center of gravity consideration, there is no risk of fall or damage to the Rover's battery. The battery is connected to copper wire which is attached to each of the motors. The intended path of these wires is through the pipes. All of the components are discussed more thoroughly in the following descriptions.

Suspension

To achieve the desired sleekness of the Rover, the design called for 0.75 inch galvanized, steel pipes. The ends of these pipes were threaded to allow for the prefabricated attachments, the main draw to this design. These attachments consisted of twelve ninety degree elbows, ten fully threaded steel nipples, six three-inch diameter flanges, two tees, two unions and a collar containing steel bearings, these components are shown below in **Figure 3**. All of the components were galvanized steel and 0.75 inches to adequately fit with all the other pieces and to ensure consistency.

Figure 3: *Suspension Arm Design*

The suspension had two independent pivot points on each side. The first pivot point is located at the connection between the body and the suspensions' bearings. The second pivot point is on the union separating the two arms of one side. This pivot point allows the Rover's back wheels to operate independently of the front wheels and the wheels on the opposite side. This is to account for unbalanced terrain on different sides of the Rover.

This design choice was successful as it was aesthetically pleasing and pivoted at the proper locations. It maintained structural rigidity with applied weight.

Body

In order to improve the containment aspect of the Rover, walls were desired as opposed to simply a frame border as with the old design. In order to accomplish this, two sheets of steel-weld metal were purchased with the intent to fold and weld the sides to create a completely surrounded box. In order to keep aesthetic appeal as the highest priority, the welds would be covered by preformed sheet-steel edges and straight metal bar. To get the straight metal bar to accurately form to the boxes' right corners, the metal was heated with a torch and molded by beating it with a hammer on an anvil. This straight metal bar covered the seam connecting the two sheets of steel-weld metal. A picture of the body can be seen below in **Figure 4** and an engineering drawing of the body can be seen in Appendix A.1.

Figure 4: *Rover Body*

The welded edges and bottom of the box were covered with right angled steel. To protect the body from warping and help it maintain its rigidity, the steel bar and edges were attached to the body with bolts. Complete symmetry was required in order to maintain balance for the center of gravity. To attach the suspension to the body, a metal rod was welded to both sides of the box, on which the suspension would pivot. The ends of these rods were threaded with a die so that the suspension would remain attached when nuts were connected.

The design of the body was structurally overengineered. However, aesthetically, the body was good looking. Therefore, as both structural and aesthetic qualifications were met the design of the body was considered a success.

Motor Housing

The motor housings for the Rover were made from the previous Rover's housings. This decision was made because the old housings were mainly aluminum plates and bars held together with bolts, making them easy to detach and repurpose.. Further, the motors for the old design were being repurposed for the new design, so the old housings would accommodate the old motors as intended.

The trouble with the repurposing of the old motor housings was incorporating a turning capability into the housings. The old turning motors for the Rover were missing at the beginning of the project. Because of this, new turning motor had to be bought and the housing for these turning motors had to be rethought. The housing for the turning motors was able to be made out of mostly old Rover parts with a few extra pieces that needed to be machined.

For the turning motors, first a plate was made that would fit the housing to the flange that fit to the pipe suspension. Holes were drilled in the plate at the points that corresponded with the holes in the flange such that they could be held together with nuts and bolts. Two additional holes were drilled in the center of the plate that corresponded to threaded holes on a thick aluminum plate. This thick aluminum plate was repurposed from the old Rover, however threaded holes had to be made. On the thick aluminum plate the turning motor was oriented perpendicular to the plate with four bolts. The shaft of the motor went through a hole drilled in the plate and connected to the housing for the driving motors. Four housing for the turning motors were made, one for each of the front and back wheels. The housing for the turning motor can be seen below in **Figure 5**.

Figure 5: *Turning Motor Housing*

The driving motors were connected to two thin aluminum plates on either side of the motor in order to fix it. This is the design the previous group used, however the motors fit into the plate in the opposite direction than intended before. This was done so that the shaft of the motor could stick out and attach to the wheels. On the side of the plates that the motor shaft was facing, parts of the plates had to be cut with a bandsaw in order for the housing to not interfere with the motor-to-wheel adapters. The thin aluminum plates were closed on the top by a thicker aluminum plate that was attached via bolts. This plate again was from the previous Rover, but holes for the bolts had to be drilled. Lastly, on the thicker aluminum plate at the top, a hole for a set screw was machined and tapped, this was so the turning motor would be fixed to the housing and be able to turn the Rover. This housing was made for all six wheels; however the middle two wheels did not have the hole for the shaft or set screw because they were not turning wheels. A picture of the housing for the driving motors and a picture of two housings connected can be seen in **Figure 6**.

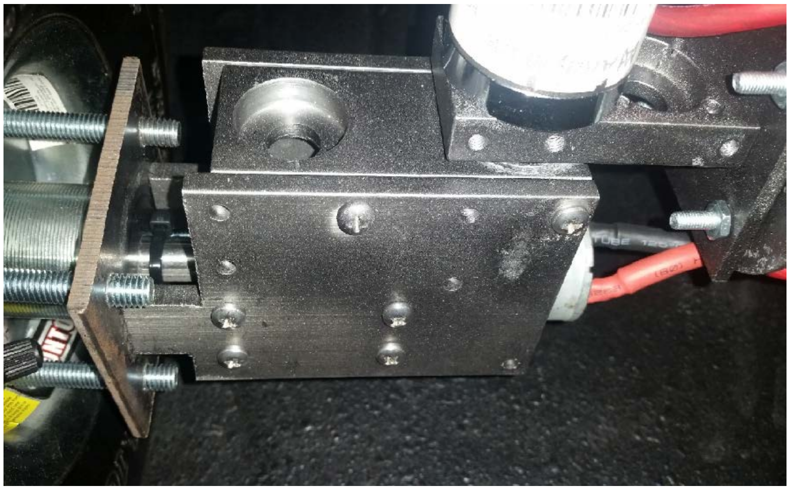

Figure 6: *Driving Motor Housing*

The challenge with the housing was finding a way to attach the turning motors; the way that they are attached now leaves the motors exposed. This is not ideal because it not as aesthetic. Another issue that came from this design for the housings was the overall rigidity of the housings, primarily in the thick aluminum plates in the driving motor housing and the steel plate that connected to the pipe flanges. The rigidity in the pipe flanges was remedied by simply tightening the screw tighter. The aluminum plate had to have more holes drilled and tapped into it to stop the wobbling of the plate.

The motor housing for the turning motors proved to be the largest problem with the overall Rover design. The design relied on the turning motors to have a locking feature such that the motor would not turn at all unless given an input. Instead, the motors freely rotated when acted on by an outside force. This caused the housing for the driving motor to rotate about the turning motors when being driven, making it so that the Rover would not go forward.

Bearing Housing

The bearing housing are made out of a collar that fits around a pipe used for the suspension and two bearings. The collar lays tight against the pipe via set screws that are built into the collar. The purpose of this part is to give the rockers full rotational ability in only one plane (the plane perpendicular to the ground being traversed). This is important because it allows the rocker to rotate and get over debris that is in its path. The one plane rotation of the rocker is crucial to the effectiveness of the rocker-bogie design.

The bearing housing was made by first drilling a 0.5 inch pilot hole with a drill press through the center of a store bought collar that fits around the pipe being used for the rocker. This pilot hole will serve as a guide for the next hole being drilled into the collar which is a 1.0625 inch hole. Unlike the pilot hole, this hole does not go all of the way through the collar, but only so deep as to fit the bearing. This is done to both sides of the collar such that a shaft can enter perpendicular to the collar and go through both bearings. This process is repeated to make two bearings housing for each of the two rockers. The drawings for this part can be seen in Appendix A.2 and the finished product can be seen in **Figure 7**.

Figure 7: *Epoxy Collar*

Originally the bearings were going to held into the collar with a two part epoxy to avoid exposed welds that would make it less aesthetic. Upon the first assembly of the rover, a lot of rigidity issues were noticed. One of the issues occurred at the bearing housings. The issue was clearly due to the epoxy, which proved too weak to hold the bearings in place. Because of this the epoxy design had to be rethought which led to the conclusion of welding the bearing housings to the collar. The welds were kept small and did not go all the way around the bearing in order to keep the aesthetic appeal of the part. The welds were then grinded down to further the visual appeal, as seen in **Figure 8**.

Figure 8: *Welded Collar*

This design was a success because it fit onto the rods on the body and allowed the Rover to have a full axis of rotation it needed to fit the rocker bogie design. The most difficult part of this part was getting it onto the rods. Because the bearing and rod were such a tight fit, the bearing housing would need to be hammered in. This led to a bearing falling off of the collar during one of the assemblies, but it was able to be welded back on.

Wheel-to-Motor Adapters

The hole for the wheel was 0.75 inches in diameter and the shaft for each driving motor is 0.5 inches. Since these sizes were different, an adapter had to be machined that would transmit torque from the motor to the wheels. The adapter would need to fit securely to both the wheels and motor in order to transmit the torque properly and be able to withstand the torque applied by the motors such that the adapter would not fail.

The wheels being used had a hub that was held together by four bolts and four nuts. The design for the adapters would use longer bolts in place of the stock bolts that came with the wheel. The bolts would be long enough to reach the shaft input two inches above the hub of the wheel. The shaft input of the wheel is where the adapter would lay.

The six adapters are made out of a 2.5 by 2.5 inch steel plate with a thickness of 0.25 inch. A drill press was used to drill holes with a 0.2031 diameter and tapped to ¼ -20 near the corners of the plate such that the long bolts going through the hub would fit into them and fix the adapter to the wheel. Next a 0.5 inch hole was drilled through the center of the plate and a 0.125 inch keyway was made with a broach. This would allow the motors to transmit torque to the wheel and drive the Rover. A picture of the adapters can be seen below in **Figure 9**.

Figure 9: *Wheel to Motor Adapter Plate*

This part went through many iterations that would attempt for adapters to lay flush with the wheel hub however due to space limitation on the wheel hub and the limitation of the Mercer machine shop, this was found to be infeasible and eventually the design described above was used.

This design was a success because it successfully transmitted the torque from the motor to the wheel. The only hang up with the design was that the bolts did get in the way of the motor housing and prevented it from rotating. This was easily remedied by cutting off the portions of the housing getting in the way with a band saw.

Wheels

Store bought wheels were chosen for the Rover to both increase the aesthetic appeal and functionality. In the previous design for the Rover, PVC pipes with sandpaper glued to them were used for the wheels. This not only contributed to the unsightliness of the design but also the effectiveness of the Rover to operate in certain terrain.

The wheels chosen for the design where intended for hand trucks and wagons, but due to the size and treads of the wheel, they were chosen as worthy parts to the new design. Six identical wheels were used for the purposes of this project. The wheels chosen are seen in **Figure 10**.

Figure 10: *Manufactured Tires*

The wheels chosen were a success because they were easily attached to the motors with the adapters and were able to function in an outdoor environment.

Wiring and Fuse Block

Two different types of wiring were picked for use in the new Mars Rover design to improve functionality. Wire, 8-gauge and 22-gauge, seen in **Figure 11**, was chosen after taking into account different factors, such as the amps being drawn by each motor and the overall power being used. The 8-gauge wire is used for the heavy duty electrical currents, such as connecting the motors to the breaker and the breaker to the battery. The 22-gauge wire is used to carry signals that control the motor controllers as well as receives information from the encoders that are on the turning motors. The previous design had been stripped of its wiring before the group came into possession of the Rover, however the wiring was attached to the outside of the suspension using zip ties, which does not look good aesthetically, as well as leaves the wires exposed to an outside environment with no protection. The new wiring will be housed within the piping used for the suspension, running through it all the way to the motors, protecting it from exposure and improving functionality as well as design.

Figure 11: *Wiring*

The fuse block chosen for the project is a Blue Sea Systems ST Blade Fuse Block, shown in **Figure 12**. It can have up to twelve different circuits that can each draw up to thirty amps. This is great enough for all the motors that are on the Rover body. It also contains storage for two extra fuses and has a protective cover. It can be used on 24-hour circuits, meaning that it can handle any duration of usage for the rover. Ring connectors are used to connect wires to the terminals and are held in place by nuts.

Figure 12: *Fuse Block*

The wiring chosen was more of a failure. While the wiring needed to be a heavy gauge, it might be possible that a better gauge of wire could be chosen to reduce the diameter. The 8-guage wiring also was coated with a type of rubber, which did not allow for it to be easily inserted into the piping or turn with the piping during assembly. It easily handled the current being output by the battery, however it did not work with the piping, meaning another type of wire must be chosen for future rover designs.

The fuse block, however, was a success. When wired correctly, no fuses were blown and the current passed successfully to the motors. Voltage was measured at several points during testing, and the correct expected voltage appeared each time, so if 12V (volts) was input, then 12V was also output to each circuit on the fuse block. The protective cover kept debris out of the main compartment.

Motor Controller

Different motor controllers were considered for the Rover design. There were different requirements that it must be capable of accomplishing, such as being durable, ease of installation, and pleasing appearance. The chosen controllers were Victor SP motor controllers. These are durable, sturdy controllers that can handle the current and voltage being run through it. With the help of the installment manual, the Victor SP is simple to install. It is also aesthetically appealing, seen below in **Figure 13**, meaning it helps with the deliverable as set forth by the client.

Figure 13: *Victor SP*

Overall, the motor controllers were a success. They did not break when fed current from the fuse block. The Victor SPs took the signal that was output by the Arduino and correctly applied it to the voltage being output by the fuse block. It then correctly limited the voltage according to the signal and output that voltage to the motors.

Microcontroller

The controller selected for driving the new Rover design is the Arduino Due. It is a microcontroller produced by Adafruit that can control different sensors and motors, as well as connecting and interpreting the signals sent from the remote control. This choice combines solutions for the present, and expandability in the future, such as adding data collection sensors and interpreting what is collected. There was no controller included in the previous design, so this decision did not take into account any flaws of the previous Rover due to having nothing on which to improve. The Arduino was not the first microcontroller selected however. Previously, the Ardupilot was selected to run the Mars Rover project. It has many high ends features that would allow the rover to perform advanced tasks, such as an autopilot feature. The problem is that while it adds features, it also complicates hooking up the rover and making it easy for someone to pick up and use. It is mostly used for quadcopters and RC helicopters, meaning there is not much documentation on using it on a Rover. Also there were not enough pins for all the motors used within the rocker bogie design and there is not really any way to use the information provided by the encoders to make the motors only turn a certain amount and not go too far when turning. Due to those problems and the Due's advantage of simplicity, the new microcontroller, the Arduino Due, **Figure 14**, replaced the Ardupilot to control the Rover's motors.

Figure 14: *Arduino Due*

The microcontroller chosen was a success because it successfully drove the motors of the Rover. It interpreted the signals sent from the remote controller and translates that signal into a number to be sent to the motor controllers. These motor controllers then use the signal to control the amount of voltage input to the motors which controls the power of the motors. The Arduino was also able to control the errors within the signal, such as it randomly spiking or changing too much to be correct.

Tests Performed

The Mars Rover was subject to four tests: the Software/Motor Control Test, 100 Yard Test, the Turning Test and the Aesthetic Test. These tests were conducted in order to determine the effectiveness of the Rover in its basic requirements of functioning remotely and maintaining aesthetic appeal.

Software/Motor Control Test

The Software/Motor Control Test consisted of running the program built to receive the remote controller input and checking the corresponding screen, displayed in **Figure 15**, output to ascertain whether the controller is working. Not only does it tell whether the signal is being sent correctly, but it also tests the microcontroller hardware and wiring as well. The test is pass or fail, but can also have one part that passes and works correctly while another part fails to pass the test. If all parts pass, then the overall test is considered a pass.

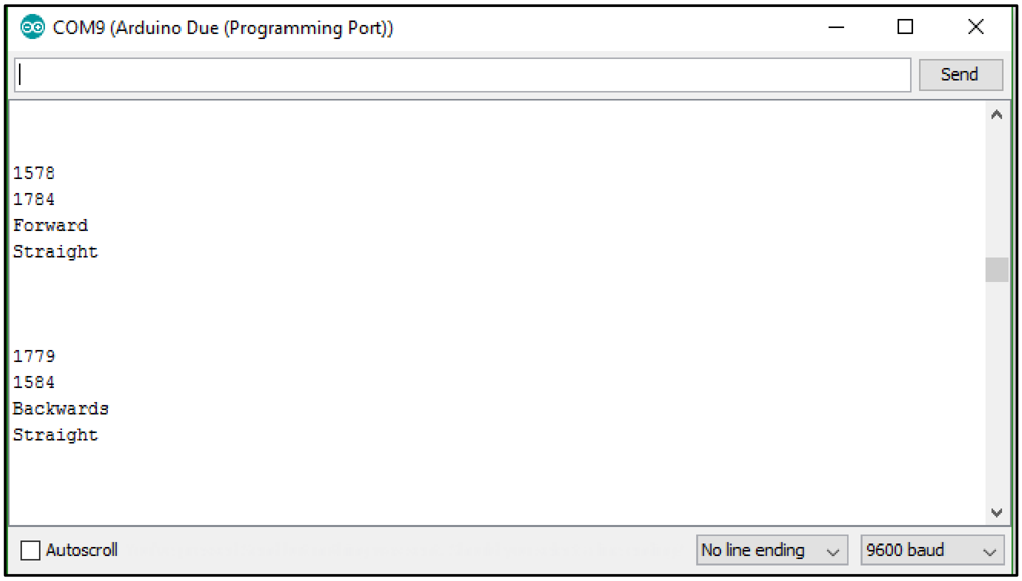

Figure 15: Software/Motor Control Test

100 Yard Test

The 100 Yard Test consisted of running the Rover over 100 yards of tilled farmland simulating the rough terrain of mars. The Rover's suspension allowed it to go these 100 yards over the rough terrain shown in **Figure 16**. This test is considered a pass or fail test. If the Rover traverses the required distance, it passes.

Figure 16: *Tilled Farmland 100 Yard Test Site*

Turning Test

The Turning Test consisted of having the Rover turn within a radius of ten feet. This tested the effectiveness of the turning motors in the suspension and flexibility the wheels offer. This test was performed on flat concrete, as opposed to tilled farmland, to assure only one variable is tested at a time. The Rover's condition of success was to make the turn at the prescribed radius. This test is either pass or fail. Success in this implies it can make a turn at any radius greater than or equal to the ten foot radius.

Aesthetic Test

The Aesthetic Test included giving a survey to twenty students and having them rate the aesthetics of the design. The test was based on a five star rating system. The survey presented a picture of the original Rover and the new Rover and asked for a rating. The results from the twenty students were averaged to compare the overall aesthetics of the design and measured whether or not the new Mars Rover succeeds in having a more aesthetic design than the previous model, as set forth by the client. If the new Rover received one star rating higher than the original Rover it was considered successful. The survey questions may be found in Appendix B. This test is pass or fail based on the results of the surveys. While it uses a rating system to calculate which design is more aesthetic, ultimately the team's new design is either better or not.

Results and Discussion

The Rover passed the Software/Motor Control test. The software correctly compiled and uploaded to the Arduino. When the remote controller was used to simulate the moving of the Rover, the output of the serial monitor correctly displayed the direction the Rover would be heading in and the speed at which it would be going in that certain direction. This means that the receiver is correctly connected to the board and relaying the proper signals for directions. This importance of passing this test is that the motors can be controlled when this software is implemented in the design of the Rover.

The results of the 100 Yard Test were a success. The Rover was able to go the full 100 yards and get over the natural obstacles of the field. This test was pass or fail; therefore there are no recorded data or tables. The passing of the test means that the Rover functions as intended and can go forward in simulated Martian terrain.

The Rover failed the turning test as it was unable to make a successful turn. As described along with the motor housing, the turning motors did not have a locking mechanism when the motor was at rest. This caused the housing of driving motor to rotate about the turning motor when the driving motors were being operated. This problem forced a design change to occur. The design change involved connecting the housing for the driving motor directly to the pipe suspension. This way the Rover could still go forward and pass the 100 yard test, but sacrifice the turning capabilities.

According to the feedback received from the scores of the surveys, the original Rover received an aesthetic score of 2.3, whereas the new Rover received a score of 3.8. This difference of scores is 1.5 stars. Therefore, this is interpreted to mean the current Rover design was more aesthetically appealing, according to the sample survey, than the original Rover because it received a difference in score higher than one star.

There were many design changes from the PDR to the final produced product. The design in the PDR had a stabilizer that kept the body of the rover level as it moved. This design was dismissed in favor of a design balancing the body at its center of gravity and placing the battery in the center of the body. This would keep the body level without needing a separate mechanism. Another change to the PDR design was the addition of the wheel-to-motor adaptors. It was known that the wheels had to be fixed to the motor, but the exact method was not determined until the wheels were purchased and an adapter for the wheels designed around its specifications. The engineering drawing for this new part is in Appendix A.3.

The budget for the Rover in the PDR was $856.21 and the amount spent on the building the rover was $1758.00. This difference was because the previous budget did not include the turning motors or the microcontrollers for each motor which added up and made the project over budget.

If this design were to be mass produced, without the turning motors included, it could be done so for under $2400 per unit. The main expense was due to the motors and controllers.

Summary and Conclusion

The Rover overall was a success because it was able to go forward and was a more aesthetic alternative than the previous design. Although the Rover as it is does not have any turning capabilities, it is considered a success because of its ability to drive and its aesthetic design.

The aesthetic design was due to the individual mechanical parts being carefully designed and the use of the prefabricated pipes for the suspension. The aesthetic value was also increased by the use of spray paint to cover the metal and make it look better visually. This is proved by the outcome of the aesthetics test that was performed.

Before moving on to the production phase, a redesign should be made so that the Rover can turn properly. This can be easily done with a turning motor that is in a locked position when at rest. After this redesign, the Rover can easily be reproduced for under $3000 per unit.

Recommendations

While the overall challenge to conquer the aesthetics of the Mars Rover by creating a sleeker design was accomplished, the adaptation of the previous group's motors added width to the current Rover. The design was still sleeker than that of the old Rover, however size was compromised. To remedy this, it is suggested to use a thicker diameter pipe in order to house the vertically-oriented turning motors and use another prefabricated pipe attachment to house the horizontal driving motors. This would not only minimize the width of the design but would also more effectively hide exposed wires.

While disassembly and repair is heightened by the prefabricated attachments, structural integrity is compromised. An improvement to the aesthetics and structure would be to use one pipe and a pipe bending apparatus rather than multiple pipes. This internal smoothness also guarantees unfettered wire movement through the pipes. Currently, disassembly cannot occur without first removing the wiring. With the proposed single pipe with a pipe bender, only one bend in the tube would be necessary to maintain the appropriate width and safe snaking of wire.

An objective of the pipe design was to have the all the wiring entirely housed within the pipes. With this, the friction factor of the wiring and diameter of the pipe becomes critical. In order to assure this occurs, two alterations must be made to the existing design. The diameter of the pipe needs to be large enough for the wire to travel freely within the pipe and not be restricted by the pipe edges. Since increasing pipe diameter is necessary for housing the motors anyway, this adjustment will align perfectly with that suggested alteration. The other alteration is to use the smallest diameter wire possible with a low friction factor. This makes snaking the wire much easier and prevents wire damage. It is also recommended to rent a drain snake. This tool will make wire travel within the pipe much easier.

Often during assemble and transition, the connections to the driving motors would break. The connections were held on with solder but the connection pin on the back of the motor snapped with frequent bending. However, the turning motors came with a plastic attachment that connected to the pins and offered protection. Instead of a direct connection, the attachment also includes a pin guide for the male wire end to just snap fit into the female pin slots. It is recommended to purchase more of these connectors and use them on all motors. This will prevent the potential for breakage and poor connection.

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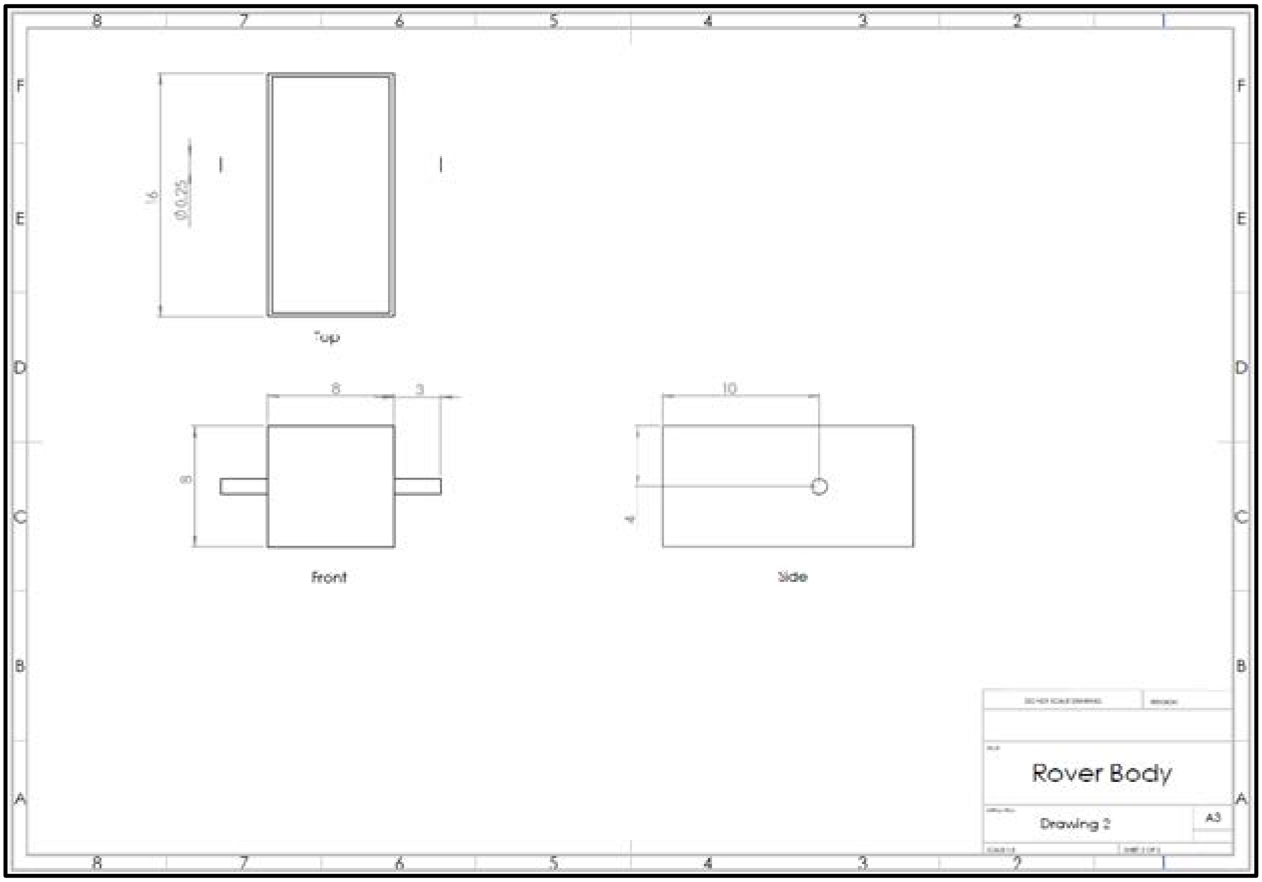
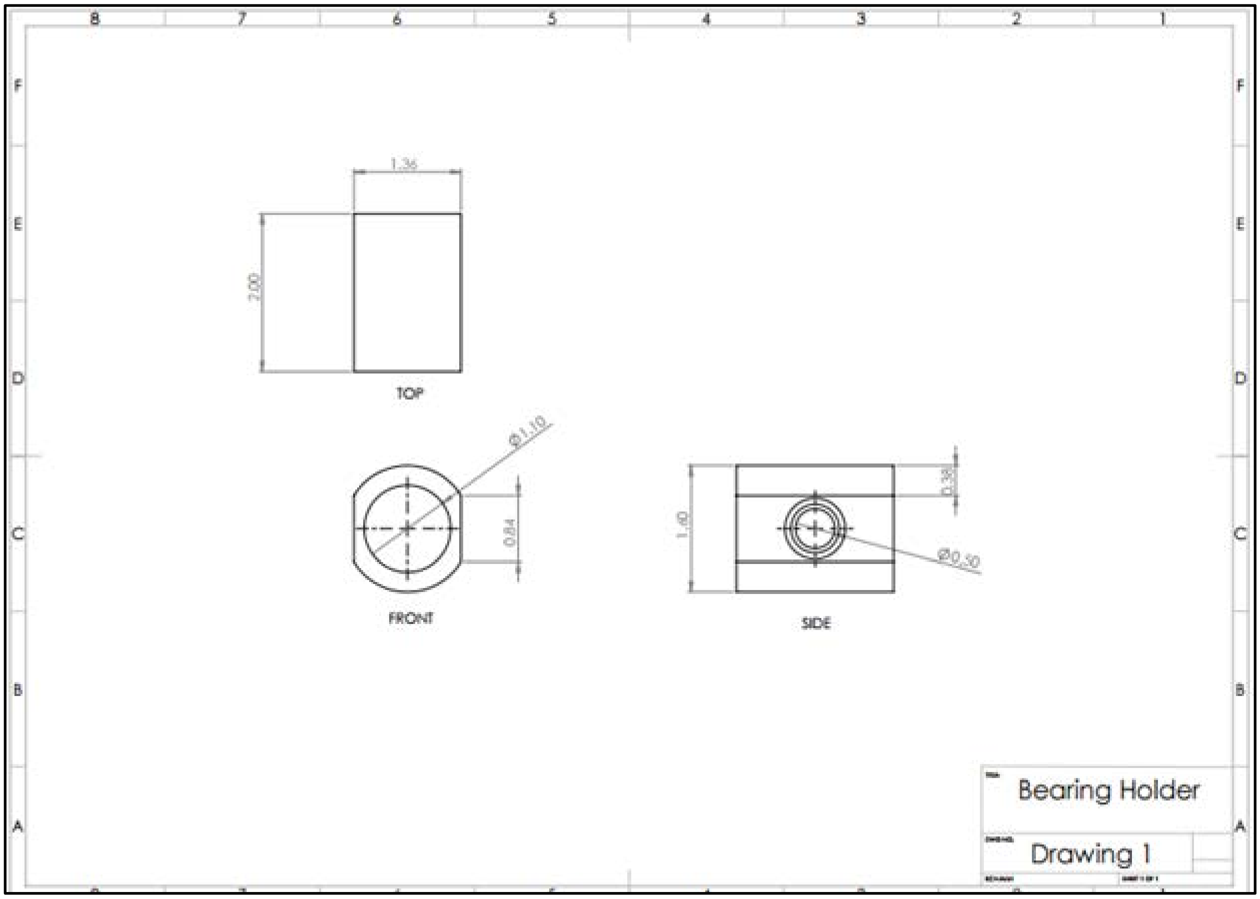
Appendix

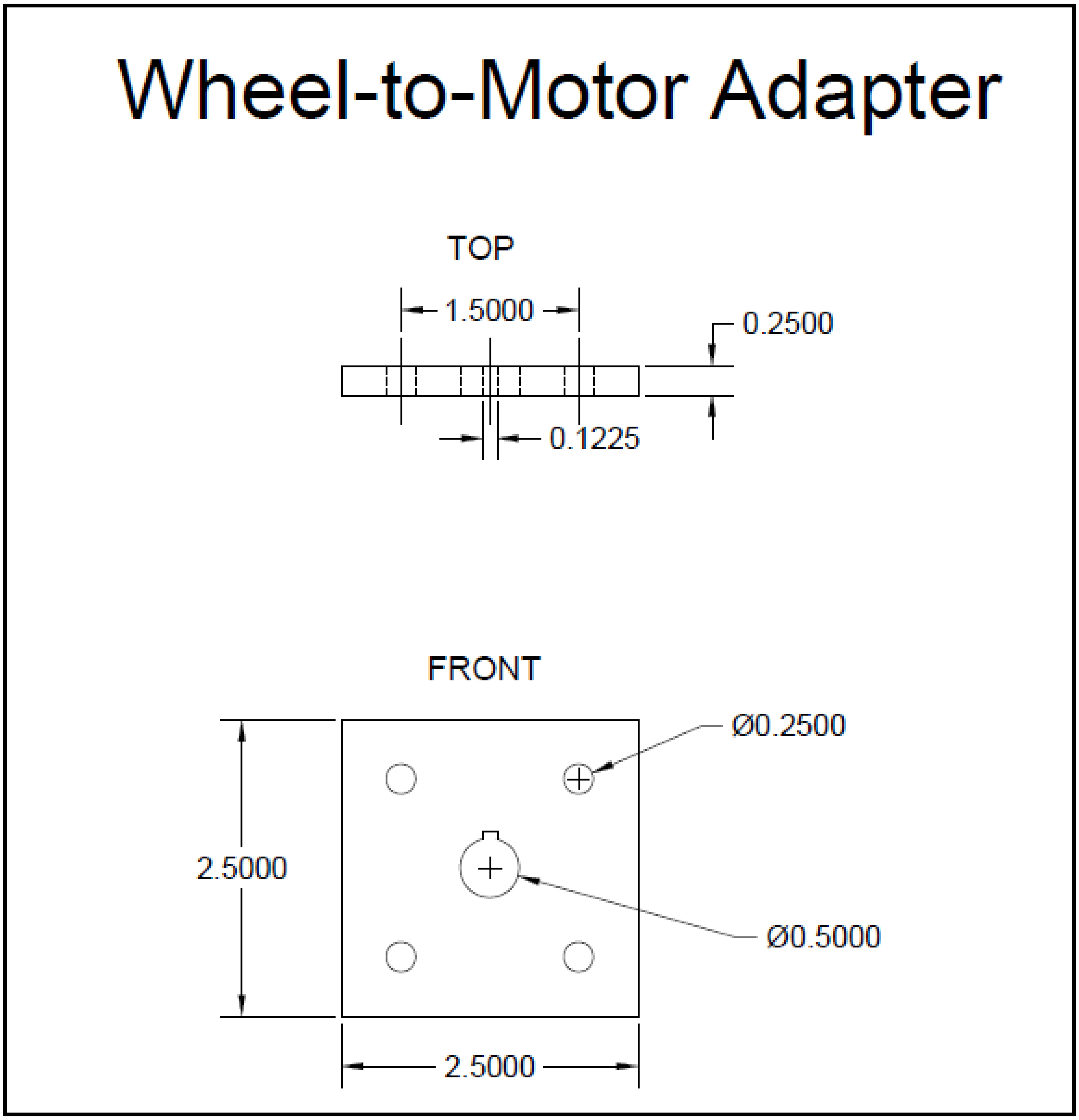
Appendix A.1: Rover Body



Appendix A.2: Bearing Housing



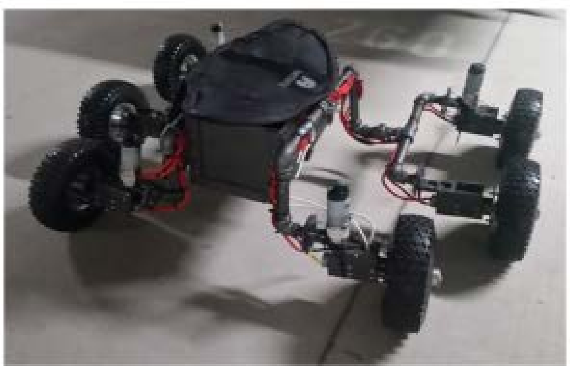
Appendix A.3: Motor-to-Wheel Adapters



Appendix B: Aesthetic Test Survey

1. How aesthetically pleasing is this Rover?

☆ ☆ ☆ ☆ ☆



2. How aesthetically pleasing is this Rover?

☆ ☆ ☆ ☆ ☆

Appendix C: Rover Manual

The numbered list below is a step by step instruction manual for starting up the rover and controlling it.

1. Find the fuse block and insert the fuses into the slots on the top of the fuse block.
2. Connect the motor controllers to the fuse block. The red wire connects to a positive terminal and the black wire connects to negative terminal.
3. Find the plastic wire connectors that have the metal plates and screws. Use these to connect the other end of the motor controllers to the wire coming from the motors. On one side of the rover, wire the two correctly, positive to positive and negative to negative. On the other side, do the opposite, connecting the positive to negative and negative to positive. This allows for the motors on both sides to move in the same direction and not in opposite directions.
4. Connect the signal input wire and ground wire from the motor controllers to the PWM signal spots on the Arduino and ground line on the breadboard.
5. Connect the power and ground spots on the Arduino to the breadboard.
6. Connect the receiver for the remote controller to the Arduino by connecting the power and ground to the breadboard and the signal inputs to the Arduino.
7. Connect the battery pack to the Arduino.
8. Load the program from a computer onto the Arduino using a cable to connect the two.
9. First making sure the power switch is in the “Off” position, connect the negative terminal of the battery to the negative terminal of the fuse block. Do the same with the positive terminal.
10. Turn on the remote controller.
11. Turn the switch on the battery into the “On” position.
12. Control the rover using the remote controller.

Appendix D: Arduino Code

```
int ch1; //channel for x_axis
int ch3; //channel for y_axis

//driving motors
int driving_one = 2;
int driving_two = 3;
int driving_three = 4;
int driving_four = 5;
int driving_five = 6;
int driving_six = 7;
String check = "Neutral";

//turning motors
int turning_one = 8;
int turning_two = 9;
int turning_three = 10;
int turning_four = 11;

float x_axis = 0; //speed of x_axis
float y_axis = 0; //speed of y_axis

//encoder information
int encoderA = 22;
int encoderB = 23;
```

```
int encoder_position = 0;
int encoder_A_last = LOW;
int encoder_A_current = HIGH;

void setup() {
  //set input pins
  pinMode(12, INPUT); // ch1
  pinMode(13, INPUT); //ch2
  pinMode(encoderA, INPUT); //encoderA
  pinMode(encoderB, INPUT); //encoderB

  Serial.begin(9600);

  //set driving and turning motors to be outputs
  pinMode(driving_one, OUTPUT);
  pinMode(driving_two, OUTPUT);
  pinMode(driving_three, OUTPUT);
  pinMode(driving_four, OUTPUT);
  pinMode(driving_five, OUTPUT);
  pinMode(driving_six, OUTPUT);

  pinMode(turning_one, OUTPUT);
  pinMode(turning_two, OUTPUT);
  pinMode(turning_three, OUTPUT);
  pinMode(turning_four, OUTPUT);

  //turn all speeds to zero
  analogWrite(driving_one, 0);
  analogWrite(driving_two, 0);
  analogWrite(driving_three, 0);
  analogWrite(driving_four, 0);
```

```
  analogWrite(driving_five, 0);
  analogWrite(driving_six, 0);

  analogWrite(turning_one, 0);
  analogWrite(turning_two, 0);
  analogWrite(turning_three, 0);
  analogWrite(turning_four, 0);
}

void loop() {

  // Read the pulse width of channels
  ch1 = pulseIn(12, HIGH, 25000);
  ch3 = pulseIn(13, HIGH, 25000);

  Serial.println(ch1);
  Serial.println(ch3);

  //calculate motor speed based off pulse width
  x_axis = (ch1 - 1700) / 2;
  y_axis = (ch3 - 1700) / 2;

  //constrain speed because of motor input range
  x_axis = constrain(x_axis, -125, 125);
  y_axis = constrain(y_axis, -250, 250);

  Serial.println(y_axis);
  Serial.println(x_axis);

  //Set direction (forward/reverse)
  if(y_axis > 20){
```

```
  Serial.println("Forward");
  check = "Forward";
  digitalWrite(driving_one, 1);
  digitalWrite(driving_two, 1);
  digitalWrite(driving_three, 1);
  digitalWrite(driving_four, 1);
  digitalWrite(driving_five, 1);
  digitalWrite(driving_six, 1);
}
else if(y_axis < -20){
  Serial.println("Backwards");
  check = "Backward";
  digitalWrite(driving_one, 0);
  digitalWrite(driving_two, 0);
  digitalWrite(driving_three, 0);
  digitalWrite(driving_four, 0);
  digitalWrite(driving_five, 0);
  digitalWrite(driving_six, 0);
}
else{
  Serial.println("Neutral");
  check = "Neutral";
  y_axis = 0;
}

//set direction (left/right)
if(x_axis > 75){
  Serial.println("Right");
  digitalWrite(turning_one, 1);
  digitalWrite(turning_two, 1);
  digitalWrite(turning_three, 1);
```

```
 digitalWrite(turning_four, 1);
}
else if(x_axis < -75){
 Serial.println("Left");
 digitalWrite(turning_one, 0);
 digitalWrite(turning_two, 0);
 digitalWrite(turning_three, 0);
 digitalWrite(turning_four, 0);
}
else{
 Serial.println("Straight");
 x_axis = 0;
}

encoder_A_current = digitalRead(encoderA);
if ((encoder_A_last == LOW) && (encoder_A_current == HIGH)) {
 if (digitalRead(encoderB) == LOW) {
   encoder_position--;
 }
 else {
   encoder_position++;
 }
 Serial.print (encoder_position);
 Serial.print ("/");
}
encoder_A_last = encoder_A_last;

if(encoder_position > 2 || encoder_position < -2)
{
 if(encoder_position > 2)
   encoder_position = 2;
```

```
  else
    encoder_position = -2;

  analogWrite(turning_one, 0);
  analogWrite(turning_two, 0);
  analogWrite(turning_three, 0);
  analogWrite(turning_four, 0);
}
else
{
  analogWrite(turning_one, x_axis);
  analogWrite(turning_two, x_axis);
  analogWrite(turning_three, x_axis);
  analogWrite(turning_four, x_axis);
}

Serial.println(check);
if(check != "Neutral"){
  analogWrite(driving_one, y_axis);
  analogWrite(driving_two, y_axis);
  analogWrite(driving_three, y_axis);
  analogWrite(driving_four, y_axis);
  analogWrite(driving_five, y_axis);
  analogWrite(driving_six, y_axis);
}
else{
  analogWrite(driving_one, 0);
  analogWrite(driving_two, 0);
  analogWrite(driving_five, 0);
  analogWrite(driving_four, 0);
  analogWrite(driving_three, 0);
```

```
    analogWrite(driving_six, 0);
  }
  Serial.print("move:"); //Serial debugging stuff
  Serial.println(y_axis);

  Serial.print("turn:"); //Serial debugging stuff
  Serial.println(x_axis);

  Serial.print("encoder count:");
  Serial.println(encoder_position);

  Serial.println(); //Serial debugging stuff
  Serial.println();
  Serial.println();
  delay(1000);
}

float mapfloat(float x, float in_min, float in_max, float out_min, float out_max)
{
  return (x - in_min) * (out_max - out_min) / (in_max - in_min) + out_min;
}
```