Milestone 9
Final Design Report
Overbuilt and Underpaid
Materials Mission
Evandro 0202

Table of Contents **Page**

Approvals

Drew Benson: x___________________________________
- Preliminary Design Shortcomings
- Final Design Drawings

Michael Donohue: x_______________________________
- Bill of Materials
- Construction Details

Andrew Lent: x___________________________________
- Structure
- Propulsion
- Product Performance and Evaluation
- Minutes

Amanda Loubnan: x_______________________________
- Executive Summary
- OSV Mission
- Gantt Chart

David Nathaniel: x_______________________________
- Product Performance and Evaluation
- Lessons Learned

Autumn Russell: x________________________________
- Cover page
- Table of Contents
- Approvals
- Executive Summary

Joey Szymkiewicz: x_______________________________
- Power
- Sensors and Actuators

Hongyu Tu x_____________________________________
- Control Algorithm

Executive Summary

Our mission for our OSV design is material identification. The basic objectives include navigating to within 250 mm of the material site, measuring and transmitting the type of material, and yielding a correct measurement. Advanced objectives involve lifting the material off the sand, and transmitting the mass the material to within 20 g of accuracy. To satisfy these objectives, our OSV design must have dimensions within 350 x 350 mm and must weigh at a maximum of 3kg. The bill of materials to assemble the OSV must not exceed $350. Our major design concepts of the OSV include a plywood base supporting our sensors and actuators. Our sensors include a tension sensor, communication module, magnetometer and proximity sensors. The actuators consist of 4 wheel motors and 2 additional motors atop the base, connected to a claw and crane. To complete our advanced mission to recognize and collect the material, we will use a magnetometer that is attached to the end of a claw, which will stem off a pulley-based crane. The OSV will move through the sand on treaded tires. We have made various torque and force calculations that tell us how to choose a suitable motor. The appropriate motor choice will enable the OSV to properly move through the sand. The OSV will be able to sense obstacles in its path using the proximity sensors. Once at the mission site the proximity sensors will also be used to navigate to within a close range of the material. At this point, we will lower the pulley allowing the claw's connected magnetometer to transmit whether the material is magnetic or not. After identifying the material, the claw will maneuver around it, and tighten its grip to sturdily grab hold of the material. In theory, our design worked well, but when the time came to perform the mission, our vehicle constantly restarted. Ultimately, we adjusted our coding to draw a lower voltage in order to prevent it from restarting. The OSV was then functioning properly, but at an extremely slow rate. It took the entire run time of 5 minutes for it to traverse the rocky strip of land. After the competition, we realized that our batteries were not fully charged enough for the motors to draw enough current for the OSV to move at the ideal rate.

Introduction

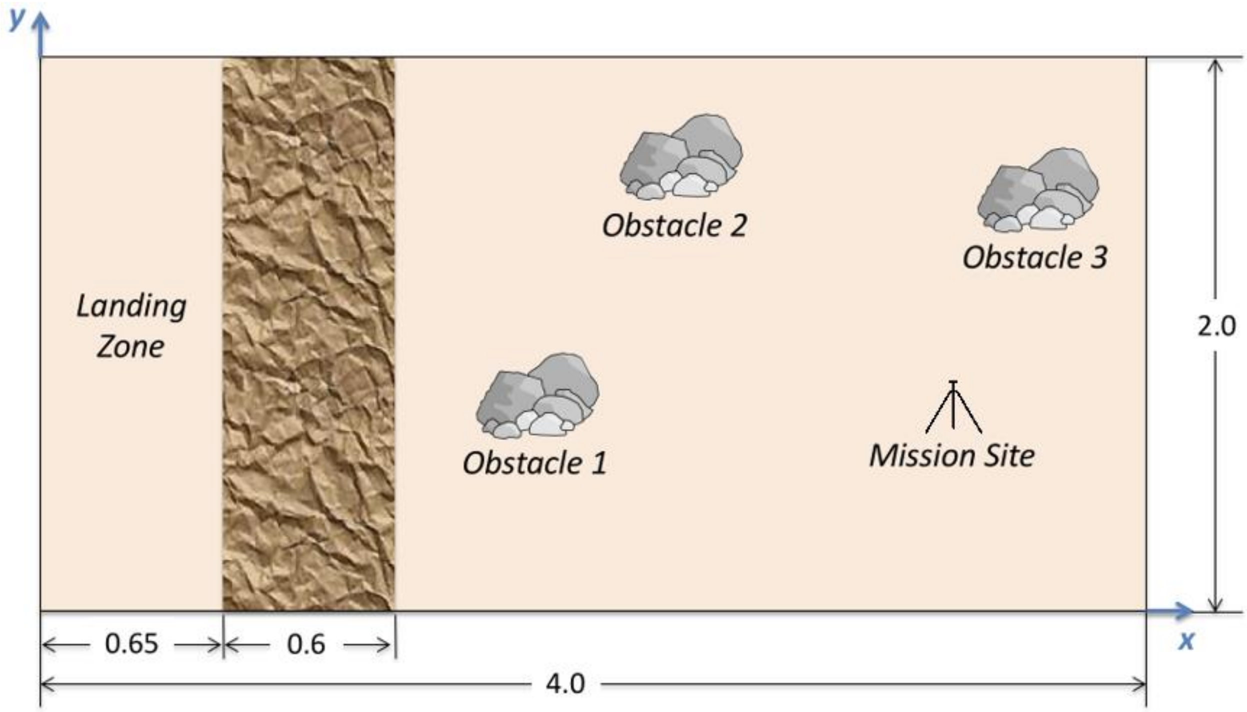


Figure 1

The objectives of our project mission are to navigate to within 250 mm of the debris (see Figure 1), measure and transmit the type of material present, as well as ensuring that our transmission is correct. The advanced objectives include lifting the material off the sand, and finding the mass of the material to within 20 g of accuracy. The design constraints for the OSV include fitting the OSV body and propulsion system within a 350mm x 350mm footprint, excluding arms or probes. Power requirements prohibit the use of lithium or lead acid batteries, as well as the use of combustion engines. The OSV must run all systems at full power for at least 10 minutes without having to recharge the battery. All of our mission requirements must be completed in under 5 minutes. Moreover, the vehicle must be able to transmit and receive RF communications via the APC220 Communication Module, must be controlled with an Arduino compatible microcontroller, and must operate autonomously. The plywood base is supported by four tires, equipped with a motor for each tire. Resting on top of the base are the communication module, 14.4 V battery, Romeo board, H bridge, breadboard, tension sensor, crane motor, proximity sensors, navigation graphic, and the pulley arm supporting the claw.

The vehicle will start on the landing zone of the 4m x 2m sandbox. The OSV will power on and navigate autonomously across the rocky strip of land . It will utilize the proximity sensors on either side of its front end to transmit any obstacles it encounters and navigate around those obstacles. The benefit of having one proximity sensor on either side is that the vehicle will account for obstacles on either side of it, therefore, preventing collisions with them and reducing any blind spots of navigation. Differential steering will allow the vehicle to turn. When approaching the mission site, the proximity sensors will sense the material and navigate to within the appropriate parameters of the material. The claw will deploy itself down towards the material via a pulley system powered by a separate motor. The magnetometer attached to the claw will be within close proximity to the debris to measure and transmit whether the material is magnetic. If the transmission yields magnetic, then the material is steel. If not, then the material is copper. Once the material is identified, the claw, with its motor, will adjust itself to open its pincers, grip the debris, and lift it off the sand. Benchmarking examples that our team drew inspiration from was the use of a claw to grab the material. Determining how the claw would be positioned on the vehicle, and how it would be deployed was critical. The basic challenges that will arise with our design include having a low center of gravity, a high predicted linear velocity, and challenges with stabilizing the claw as the OSV navigates precisely to the mission site. Our plan to reduce the impact of these challenges will be attaching weight under the chassis, utilizing pulse width modulation to reduce the velocity, and confirming that the claw is stable and wound up the pulley, away from the range of the proximity sensors.

Once we deployed these tactics the OSV did not perform as we had hoped due to the amount of current supplied to the romeo board. The romeo shorted which caused the code to start from the beginning and continuously repeat. This leads to our OSV continuously driving in circular pattern. To try to counteract this issue we altered code to lower the current output. Sadly we overcompensated for this issue causing the OSV to move at an extremely slow speed. Our OSV had the capabilities to complete the mission but ended up barely making it over the rocky terrain due to the issues with the romeo. The miscalculation could have also been caused by a lack of time to complete test runs.

Design Details

Preliminary Design Shortcomings

The preliminary design had a few problems that were fixed by the final iteration of the OSV. These issues were resolved quickly in a rather straightforward fashion. A few of these design flaws include the motor mounts, the tension sensor, and the proximity sensor. The first issue we foresaw was the problem with having handmade motor mounts. The initial motor mounts would be a small piece of plywood with a hole drilled through so the motor could be stuck through. This idea was scrapped when one was modeled as it was very hard to replicate. Instead of using these pieces of plywood, motor mounts were printed. These motor mounts were tight around the motors, and much more exact than the plywood could ever be, meaning that the motors would be more straight, and the motor mounts would be less likely to break.

In the preliminary design, the battery was planned to be stationed on the top of the back of the OSV. This changed when we realized that there wouldn't be enough room for the crane and motor that runs it, a bread board, the Arduino, locator table, and the battery. We quickly had to come up with a solution that would save space. We chose to move the battery under the OSV. We accomplished this by printing a small structure that would hold the battery under the vehicle, and allow it to easily slip in and out. One of the shortcomings of this method, however, is that the battery was often difficult to slip in and out, and when the battery was oriented in some directions, it wouldn't slip in at all. Our team made the assumption that we would be able to fit all of the necessary parts to our OSV on top of the plywood. This assumption was likely made because the battery in the CAD is noticeably smaller than that which we used.

Final OSV Designs

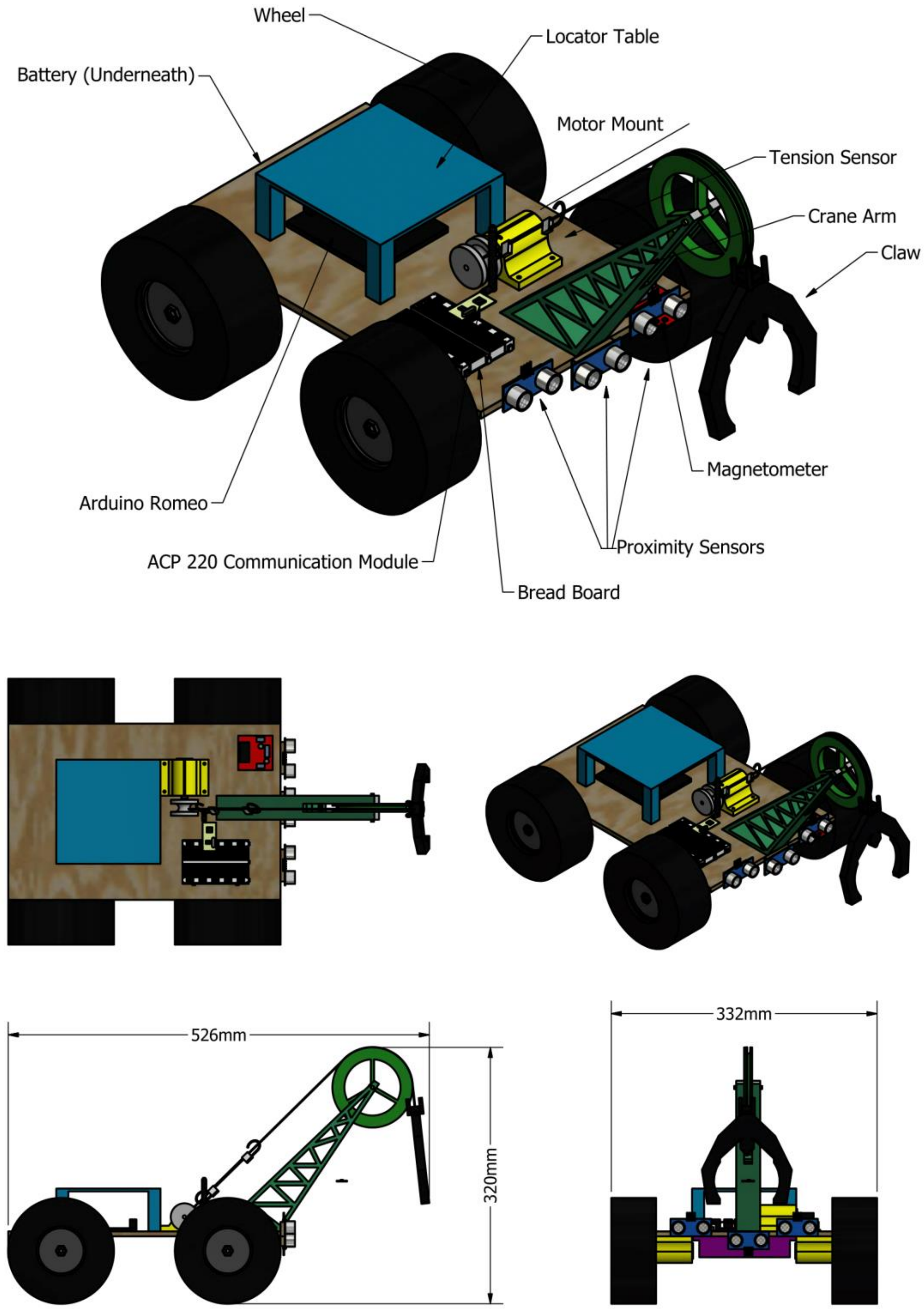


Figure 2&3

Structure

The OSV is built on a 220mm by 340mm piece of plywood which acts as the main base to which everything is attached. The motors are held in 3D printed motor mounts which are themselves attached to the underside of the plywood base with four screws and nuts each (See Figure 4). The hex adapters are attached to the motor shafts and tightened with set screws, and the wheels are then attached using a screw that is threaded through the wheel and into the centroidal axis of the hex adapter. The tires we use have some tread, as it was difficult to find tires at the correct size that did not have much tread. The tires have a diameter of 132mm and a width of 56mm. The battery is located underneath the the OSV in a 3D printed mount. The battery mount is attached to the plywood base using four screws and four nuts. The QR code which allows for accurate transmission of the OSV's location is on a small 3D printed platform. The 3D printed platform is secured to the plywood base using hot glue. The Romeo Board is beneath this table as it is a good, central location. The voltage regulator rests next to the Romeo Board and the H-Bridge sits near the front just left of the crane. These are good locations as they are close to the Romeo Board and crane respectively, so wires do not need to be that long to connect everything. There is a breadboard located near the front of the OSV, which allows for more motors and sensors to be run off the Romeo Board. There are three proximity sensors located on the front of the OSV, which allow for the detection of obstacles. We chose to use three because the cone of detection for a single proximity sensor was not large enough to detect obstacles across the entire vehicle. The H-Bridge, voltage regulator, breadboard, and proximity sensors are attached using velcro.

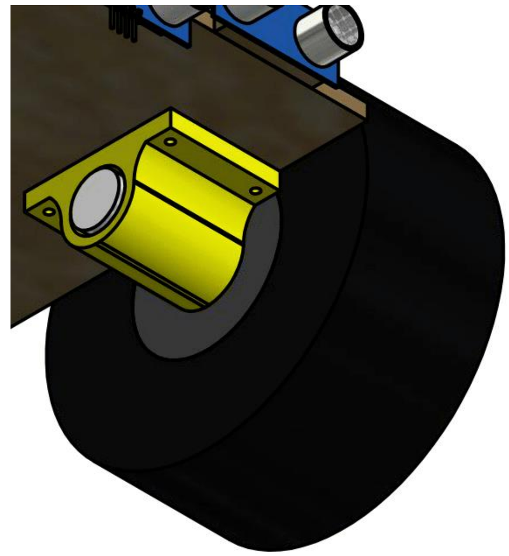
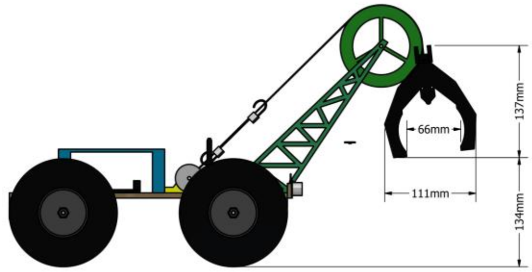


Figure 4

Figure 5

The crane system is composed of a 3D printed arm, the motor system, the pulley system, and the claw. The arm extends forward and up, hoisting the pulley system and the claw so they will not be dragged on the ground. The arm extends 210mm upwards and 140mm in front of the OSV. The pulley wheel brings the total height added by the system to 230mm high and 165mm outwards from the front base of the OSV (See Figure 5). The claw has 134mm of clearance from the ground and can open up to 66mm. On one end of the string, there is the claw that will pick up the materials, and on the other there is a motor which raises and lowers the claw with a string.



This motor is the exact same as the other motors we are using as that motor fits the torque requirements needed to lift the debris. It is attached with a motor mount, just like the other four. To measure the mass of the debris, we use a tension sensor which changes its resistance based on the amount of tension in the string, also known as the amount the tension sensor stretches. That change in tension is directly related to the mass on the other end of the crane. We can then use the voltage drop across this resistor to calculate the mass. The claw can be opened and closed with the built in motor. Once a voltage is applied to the crane motor, it opens and closes based on which direction the current is flowing which is controlled by the H-Bridge and the Romeo board. While the OSV is driving around, the claw will be completely raised and held against the plastic wheel by putting the string it is attached to in tension. This will prevent the claw from swinging around as we drive and prevent it from getting stuck on any obstacles on the course.

Mass Table Table 1

Parts	**Manufacturer/Vendor & Model Number**	**Description**	**Mass (g)**
Motors (x5)	ServoCity, #638388	65 RPM Mini Econ Gear Motor, planetary style	226.5
Battery	AA Portable Power Corp., #CU-J1214	14.4V 3.2Ah NiMH Battery	535
Communication module	Dfrobot, SKU: TEL00005	APC220 Communication Module	30
Wheel (x4)	Revolver/ServoCity, #82062	Revolver Robot Wheel	127
Romeo Board	Romeo/Dfrobot, SKU: DFR0004	N/A	60
Hex Shaft Wheel Adapter (x4)	ServoCity	Attaches wheel to motor shaft	48.4
Kill Switch Wire	Lynxmotion, #WH-01	Wire located between battery and Romeo Board	18.144
Magnetometer	Amazon, SMAKN GY-273 HMC5883L 3 Triple Axis Compass Magnetometer Sensor Module 3V-5V	Triple Axis Magnetometer	15
Wood Board (467500 mm^3)		Plywood base	290
Tires (x4)	ServoCity, #595646	Off Road Tires	380

Proximity Sensor	Banana Robotics, #HC-SR04	Ultrasonic proximity sensor	56
Claw	MakeBlock/RobotStop, #RB-Mab-106	MakeBlock Robot Gripper	200
Motor Mount (x5)		3D Printed Motor Mounts	100
PLA Crane (117741.042 mm^3)		3D Printed Crane Arm	147.2
PLA Crane wheel (19142.411 mm^3)		3D Printed Wheel that will sit on the top of the crane arm and act as a pulley for the string	23.9
PLA OSV Postition Tracker (64000 mm^3)		3D Printed Table that will have the location image tracker on top	80
Hbridge	Qunqi C/Amazon, #MK-050	Controls direction of additional motors	27.2
Stretch Sensor	Gravity & Wheatstone/RobotStop, #RB-Dfr-519	Wire with conducting terminals that changes resistance under tension	10
Bread Board		Creates extra ports for wiring	38.9
Battery Mount		3D Printed Battery Mount	90
Voltage Regulator	SparkFun, #COM-12766	Modulates voltage from 14V to 12V	3
Total Mass			**2416**

Propulsion

Figure 6

We chose to use the Revolver Robot Wheels and Off-Road Tires (see Figures 7 and 8, respectively) which have a diameter of 132mm and a width of 56mm. We decided on using such large tires because they helped us work out our tractive effort calculations. The rover uses differential steering in order to turn. This is accomplished by

Figure 7

stacking motors on the same side of the vehicle in the same Romeo Board motor port, and running one side forward and the other backward to turn. For example, by running the left motors forward and the right motors backwards, we can turn right. The opposite works for turning left. Our tractive effort calculations anticipated a center of gravity with a distribution of 60% to 40%, meaning that the center of gravity will be located 60% from the back. We also specified the center of gravity to be 8cm from the ground. We chose this center of gravity in anticipation of having the crane out in front of the rover, and because it made the tractive effort inequalities work out well.

Variable Definitions

W = Weight of the rover
W_x = X component of the weight of the rover
W_y = Y component of the weight of the rover
F_{NF} = Normal force on the front tire
F_{NR} = Normal force on the rear tire
C_{RRF} = Coefficient of rolling resistance on front tire
C_{RRR} = Coefficient of rolling resistance on rear tire
F_{RRF} = Force of rolling resistance on the front tire
F_{RRR} = Force of rolling resistance on the rear tire
F_{SlideF} = Force of sliding friction on the front tire
F_{SlideR} = Force of sliding friction on the rear tire
F_{TE} = Force of Tractive Effort
μ= Coefficient of sliding friction
d_1 = Distance from the rear axle to the center of gravity
d_2 = Distance from the front axle to the center of gravity
h = Distance from the ground to the center of gravity

Tractive Effort Calculations at 0º Incline

$\Sigma F_y = 0 = F_{NR} + F_{NF} - \frac{W}{2}$

$\Sigma M_A = 0 = F_{NF} * (d_1 + d_2) - \frac{W}{2} * d_1$

$F_{NF} = \frac{\frac{W}{2}*d_1}{(d_1+d_2)} = \frac{\frac{29.4N}{2}*125mm}{(125mm + 83mm)} = 8.82N$

$F_{NR} = -F_{NF} + \frac{W}{2} = -8.82N + \frac{29.4N}{2} = 5.89N$

$C_{RRF} = (3.33\frac{cm^3}{N} * \frac{F_{NF}}{w*d^2})\frac{1}{3}$

$= (3.33\frac{cm^3}{N} * \frac{8.82N}{5.59cm*(13.2cm)^2})\frac{1}{3} = 0.311$

$C_{RRR} = (3.33\frac{cm^3}{N} * \frac{F_{NR}}{w*d^2})\frac{1}{3}$

$= (3.33\frac{cm^3}{N} * \frac{5.89N}{5.59cm*(13.2cm)^2})\frac{1}{3} = 0.272$

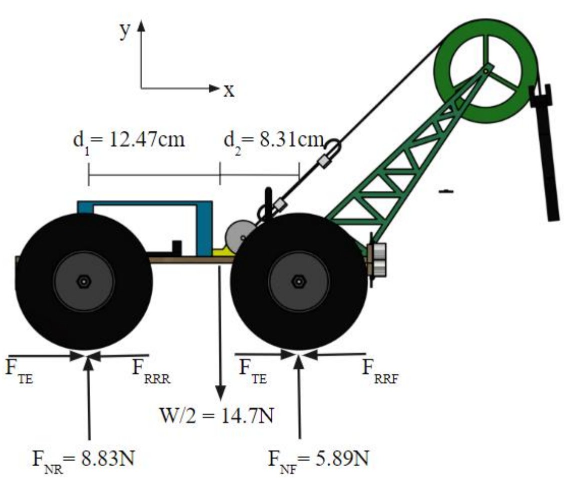
$F_{RRF} = F_{NF} * C_{RRF} = 8.82N * 0.311 = 2.74N$

$F_{RRR} = F_{NR} * C_{RRR} = 5.89N * 0.272 = 1.60N$

$F_{SlideF} = F_{NF} * \mu = 8.82N * 0.7 = 6.17N$

$F_{SlideR} = F_{NR} * \mu = 5.89N * 0.7 = 4.12N$

Figure 8



Tractive Effort Calculations at 30º Incline

$W_y = \frac{W}{2}*\cos(\Theta) = \frac{29.4N}{2}*\cos(30^o) = 12.7N$

$W_x = \frac{W}{2}*\sin(\Theta) = \frac{29.4N}{2}*\sin(30^o) = 7.35N$

$\Sigma F_y = 0 = F_{NR} + F_{NF} - W_y$

$\Sigma M_A = 0 = F_{NF} * (d_1 + d_2) - W_y * d_1 + W_x * h$

$F_{NF} = \frac{W_y * d_1 - W_x * h}{(d_1 + d_2)} = \frac{12.7N * 125mm - 7.35N * 80mm}{(125mm + 83mm)} = 4.81N$

$F_{NR} = -F_{NF} + W_y = -4.81N + 12.7N = 7.92N$

$C_{RRF} = (3.33\frac{cm^3}{N} * \frac{F_{NF}}{w * d^2})^{\frac{1}{3}}$

$= (3.33\frac{cm^3}{N} * \frac{4.81N}{5.59cm * (13.2cm)^2})^{\frac{1}{3}} = 0.254$

$C_{RRR} = (3.33\frac{cm^3}{N} * \frac{F_{NR}}{w * d^2})^{\frac{1}{3}}$

$= (3.33\frac{cm^3}{N} * \frac{7.92N}{5.59cm * (13.2cm)^2})^{\frac{1}{3}} = 0.300$

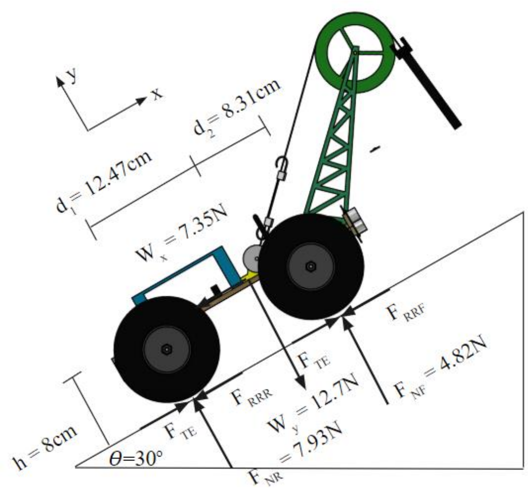
$F_{RRF} = F_{NF} * C_{RRF} = 4.81N * 0.254 = 1.22N$

$F_{RRR} = F_{NR} * C_{RRR} = 7.92N * 0.300 = 2.38N$

$F_{SlideF} = F_{NF} * \mu = 4.81N * 0.7 = 3.37N$

$F_{SlideR} = F_{NR} * \mu = 7.92N * 0.7 = 5.54N$

Figure 9



Tractive Effort Inequalities

$F_{RR} < F_{TE} < F_{Slide}$

$1.60N < F_{TE} < 4.12N$

$2.74N < F_{TE} < 6.17N$

$1.22N < F_{TE} < 3.37N$

$2.38N < F_{TE} < 5.54N$

Final inequality: $2.74N < F_{TE} < 3.37N$, choose $F_{TE} = 3N$

Figure 10

Motor Selection

We calculated the required torque based on our chosen tractive effort and the radius of our tires:

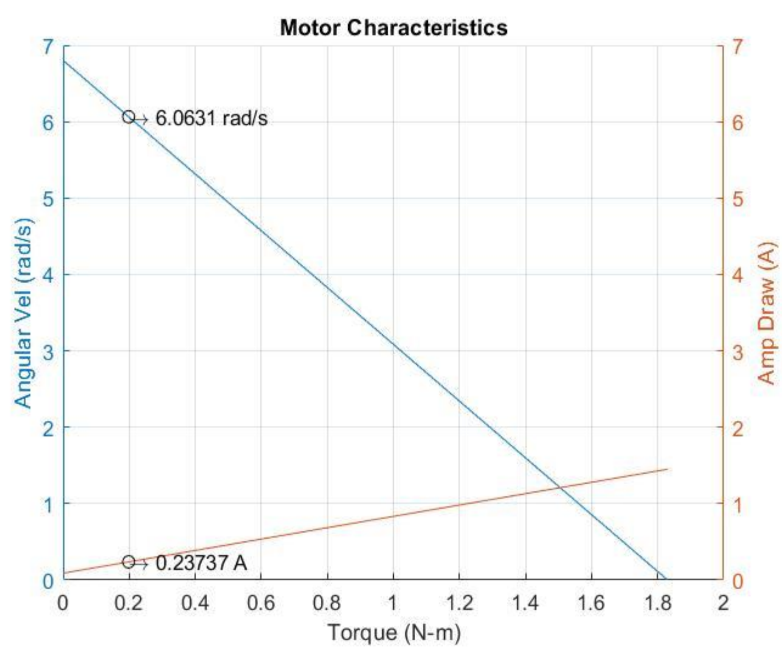
$\tau = 3N * 0.0661m = 0.198N\text{-}m$

At 0.198N-m, the motor operates at an angular velocity of 6.06 rad/s (See Motor Characteristics Graph). From this, we can calculate our linear velocity by multiplying our angular velocity by the radius of our tires:

6.06 rad/s * 0.066m = 0.4m/s

According to the Motor

Graph 1



Characteristics Graph, our amp draw at 0.198 N-m is 0.237A per motor. The power output of each motor can be calculated by multiplying the current draw by the operating voltage of the motor:

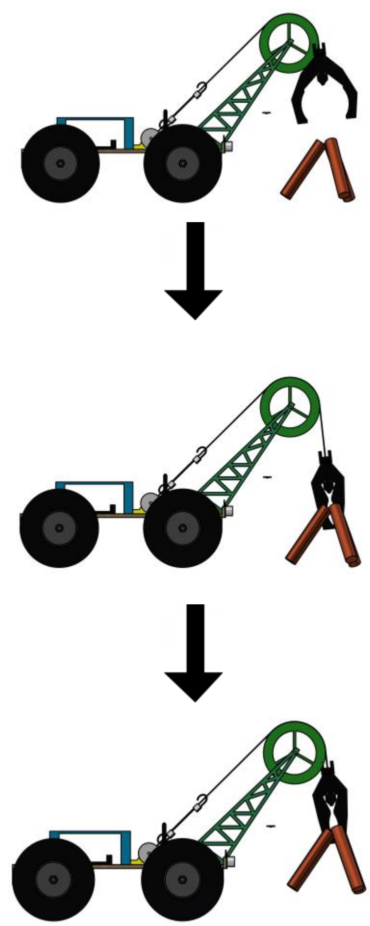
$$P = I*V = 0.237\ A * 12V = 2.84\ W$$

Our propulsion system performed flawlessly when everything on the bot was working correctly, meaning there was nothing wrong with the code or the electrical subsystems. The motors did not dig us into the sand, nor did we move too fast. We were able to navigate the rocky terrain without issue; we could even turn on the rock terrain. Overall, the propulsion did not cause issues with the final rover.

OSV Mission

Our mission involved navigating across rocky terrain to within 250 mm of the material site, transmitting the identity of the material, and lifting the material off the sand to measure its mass. We were going to sense the obstacles using our proximity sensors. Once we arrived at the mission site, we were going to use a combination of the proximity sensors and data from the communication module to locate the tripod in front of us. Then we were going to use the magnetometer and compare the reading at the moment to a reading taken near the beginning of the mission. If the angle read was lower then we knew we had steel in front of us and if not then we had copper. Finally, the crane motor would lower the claw, the claw would close around the material, the crane motor would raise the claw so the material was off the ground, and the tension sensor would read the mass of the material (See Figure 11). The only portion of our mission that our OSV performed was navigating across the narrow strip of land. The vehicle was performing at a lower pulse width modulation, and was moving very slow. As a result, it took the entire run time of five minutes for the OSV to move across the rocky strip. On the day of the competition, during our test runs, we noticed that the vehicle would automatically reset itself in the middle of propagation by turning continuously in a circle. At the time, we thought that we were somehow shorting our romeo board, and that the vehicle was drawing too much

Figure 11



current. Our next theory was that our switch was faulty and causing the vehicle to reset. After using another switch, the same problem with the vehicle persisted with our test runs. We decided to alter the programming to have the vehicle draw less current. Due to this, our vehicle moved too slow to perform the whole mission in time. After the competition, we reasoned that even though our batteries were charged enough to run the vehicle, they were not fully charged. Other teams had similar problems with their vehicles restarting due to having batteries that were not fully charged. This is the main reason we believe why the OSV gave us problems, and ultimately operated at a very slow rate.

Power

Our Romeo Board accepts 7-12 volts and our motors run optimally at 12 volts, so we decided to supply our motors and board with with 12 volts. We use a voltage regulator to help maintain a constant voltage as the battery life depletes. For this reason we will be using a 14.4 volt battery. We took a very conservative estimate to our battery calculations. We assumed that we would be running our motors, sensors, claw motor, crane motor, and Romeo Board for the full time. The sensors, claw motor, crane motor, and Romeo Board combined will draw no more than 500mA. We also factored in a conservative safety factor because our OSV will not be running all of its sensors and motors throughout the entire mission. Using these assumptions we calculated our necessary battery capacity.

Figure 12

237mA * 4 motors + 500mA = 1448mA

1448mA * 2hr (full class) = 2896mAh

2896mAh * 1.036 = 3000mAh

We chose to use a 14.4V 3.2Ah battery. Our 14.4 volt battery passes through a 12 volt regulator, feeding the Romeo Board 12 volts. The regulator also feeds to an external H-Bridge 12 volts. The Romeo Board is in charge of running the propulsion motors, sensors, and telling the external H-Bridge when to operate the claw and crane motors. The left propulsion motors will be wired to one motor port on the Romeo, a 12 volt output, and the right propulsion motors will be wired to the other 12 volt motor port on the Romeo Board. We connected our three proximity sensors, our communication module, magnetometer, and tension sensor to the 5 volt output on the Romeo Board.. The last two motors, the claw and the crane, are each hooked to one of the two external H-Bridge outputs. They are controlled by the Romeo Board, but fed 12 volts from the external H-Bridge.

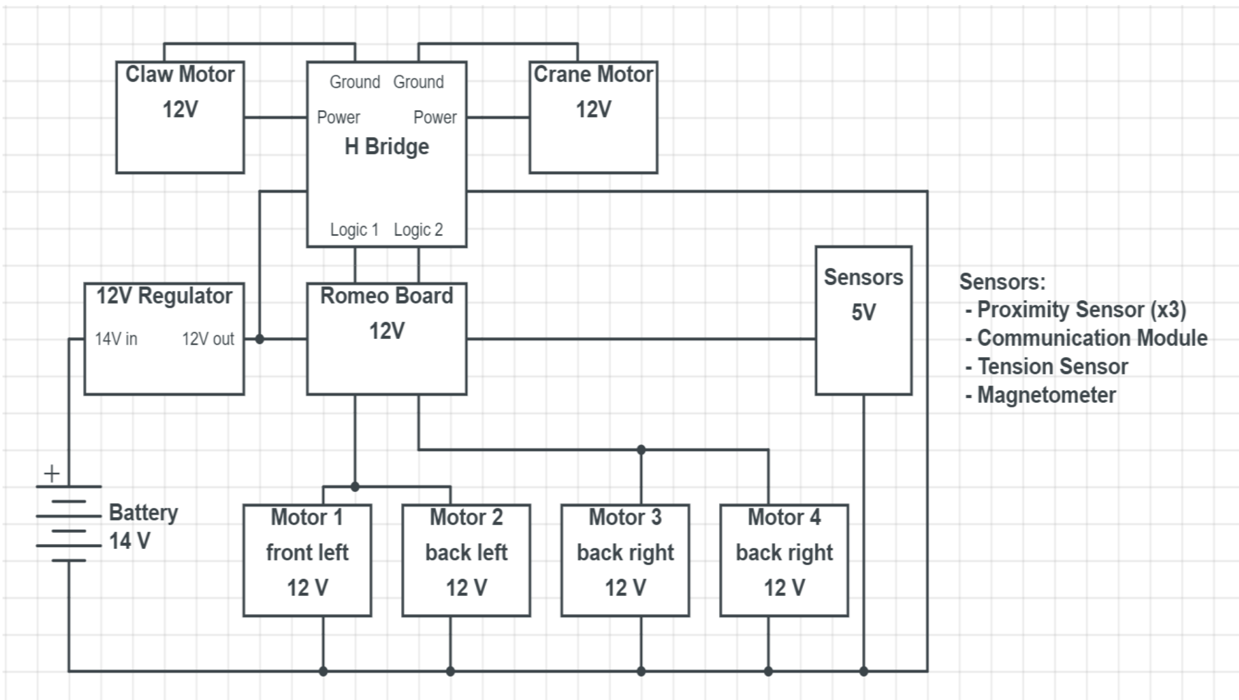


Figure 13

Due to our OSV's maximum speed of 0.4 m/s, we use pulse width modulation to provide less power to our motors. This quickly turns on and off the signal from the Romeo Board to the four motors, making the vehicle seem like it has a continuous flow of current while preventing the velocity from reaching its max of .4 m/s. We plan to run around 5 cm/s. With a worst case travel distance of 9m, this makes our expected travel time:

$t = d/v = 9m / (0.05m/s) = 180$ seconds

This is still gives us 120 seconds to complete the missions which is plenty of time to pick up the material, identify it, and weigh it.

Our power systems performed flawlessly until the actual competition. During the competition, our Romeo boards kept resetting. At first, we thought it might be a loose connection or a problem with the kill switch, but the problem kept occurring even after we checked everything and replaced the switch. We came to the conclusion that either our motors were drawing more current than we quoted them at, or because our batteries had not been completely charged the night before. Ultimately, the failures in our power subsystems most likely did not come from an issue with the actual equipment, but rather human error.

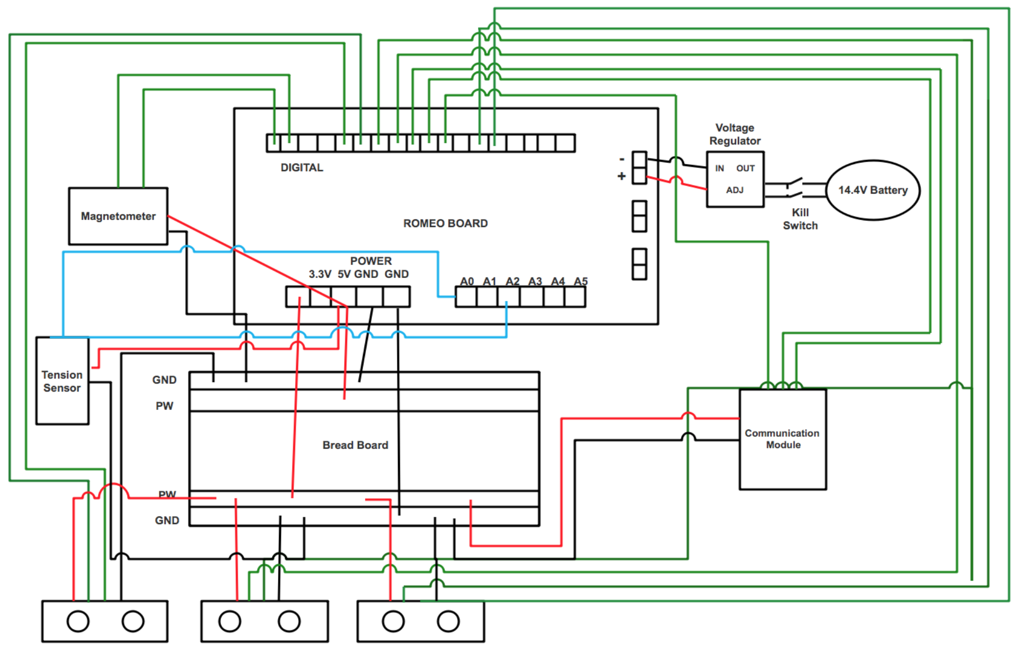


Figure 14

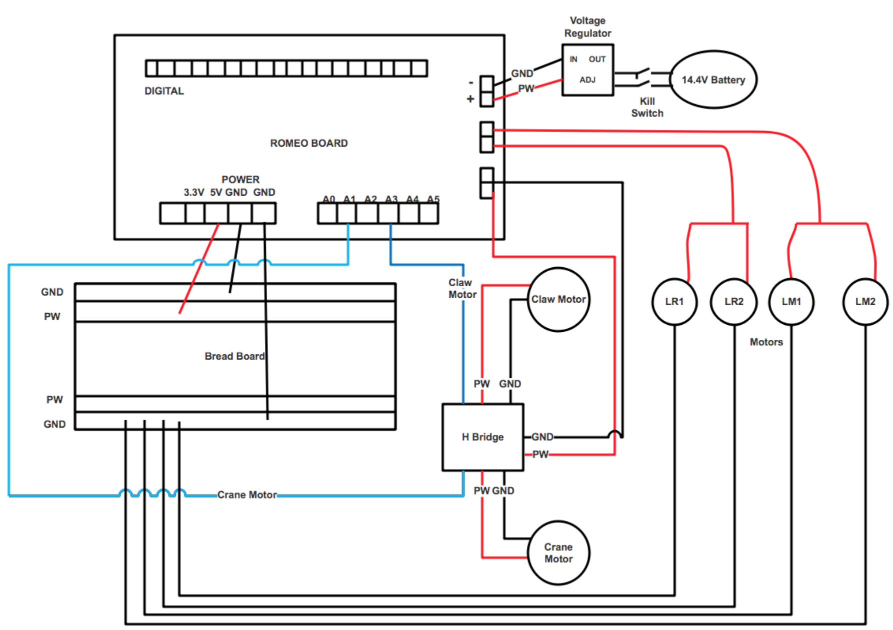


Figure 15

Sensors and Actuators

The OSV used three proximity sensors, a stretch sensor, a magnetometer, a crane motor, and a claw. These sensors allow the OSV maneuver around obstacles, and detect information about the material that the mission specifications require. All of these sensors and actuators, except the two motors, run from a 5V power supply from the Romeo board and are grounded to the breadboard and then back to the Romeo's ground pin. Along with power and ground, the proximity sensors have two other leads that were connected to the digital inputs on the Romeo. Similarly, the communication module also had two leads connected to the Romeo's digital pins. The stretch sensor had a power and ground lead. The ground lead was run to the breadboard and from there it was run through a resistor to the ground port and through another wire back to one of the the Romeo's analog pins. The magnetometer had two leads running to power and ground along with two running to two analog pins on the Romeo board. The claw motor and crane were run through an external H-bridge. The H-bridge receives power directly from the voltage regulator. It has two leads running to digital pins on the Romeo. The crane motor and the claw accept 12V and both have power and ground leads running from the external H-bridge.

Proximity Sensors

The OSV was equipped with three proximity sensors. They are located in the front, with one on each side of the crane arm and one right underneath the crane, all three are facing forwards (See Figure 16). The OSV used these sensors to detect obstacles on both sides so it can determine how it can get around the obstacle in front of it. For example, if only one sensor is detecting an obstacle, the OSV would turn towards the side which is not detecting the obstacle, move until it thinks it has cleared the obstacle, turn back towards the mission site, and continue on. The proximity sensors will be feeding information back to the Romeo Board which will then decide what is the best path to take and supply power to the wheels.

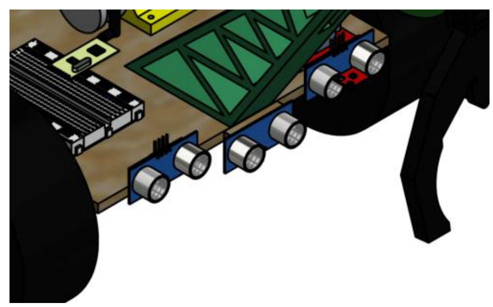


Figure 16

Magnetometer

The magnetometer (See Figure 17) is attached to the the side of the crane arm so it will be able to test the magnetic force of the sample

material before it is picked up. Placing it here allows for the sensor to be able to be close enough to the sample so it can get an accurate reading without having any interference from the claw. The reading is taken before the claw picks up the sample. Based on the magnetic force we will be able to tell whether our sample is copper or steel. The Romeo board will tell the

Figure 17

Magnetometer when to take the sample and will receive the reading from the magnetometer.

Claw

We attached our claw to the front of our OSV, on our crane arm, so that it will be able to reach the sample material and pick it up. The claw will be attached to a string that will allow for it to be raised and lowered. This will allow for our claw to be raised and secured out of the way of our proximity sensors, to ensure proper readings for navigation. Then when the OSV reachesthe mission site, the claw will be lowered

Figure 18

and the Romeo Board will tell the claw’s built in motor when to close the claw to grab the material.

Crane motor

The crane motor is located in the center of our OSV behind the crane. We have decided to place it here so that it will be able to release or contract the string that will lower or raise the claw. The motor is powered through our external H-Bridge. The Romeo Board will be in charge of telling this H-Bridge when to give the crane motor power to lower or raise the claw.

Stretch Sensor

Our stretch sensor is attached in the middle of the string holding the claw. One end of the string will be running towards the motor and the other end of the string will be running toward the crane wheel. Here, the stretch sensor does not get in the way of the string traveling over the crane arm wheel, when the claw is being lowered, or being raped around the spool, when it is being raised.. We will run 5V through the stretch sensor and read the voltage drop that occurs due to the tension on the sension an interpret the weight that is on the end.

Figure 19

Communication Module

The APC220 Communication Module is attached to and wired through the breadboard. The communication module allows to remotely communicate with another APC220 to pinpoint our location and navigate to the mission site.

Control Algorithm

To complete the mission, our OSV will first use the RF module to communicate with the central computer, retrieving location information including the x and y coordinates of the starting point of the vehicle and the destination, and initial orientation of itself. After having all the information that will lead it to the destination, the OSV turns itself to 90 degrees, which allows it to move in either the +y or -y direction, lining itself up with the destination. Since there are no obstacles before crossing the terrain, in this step our OSV will only be moving inside the landing zone. From our testing, we found that the combination of a 0.2 second duration of the motors for one tiny step allows the car to travel a considerable distance in a reasonable time. So, the vehicle will keep taking small steps until it reaches the re-set destination, which is the y coordinate of the mission site. Then the car will turn back to 0 degree facing directly toward the mission site. It will then cross the terrain and stop before going into the other side where obstacles could exist.

Our algorithm for obstacle avoidance takes full advantage of how the mission was set up since the whole side was divided into four quadrants, which have obstacles in the front two and one mission site and one obstacle in the back back. Once the OSV is stepping into the front two quadrants, which are from 1.25 to 2.65, it will start to use three proximity sensors we installed in front to detect whether there is an obstacle within a 40 cm range. The OSV will keep moving until it reaches the mission site if there are no obstacle in between. But, if there are obstacles in front, the OSV will first find out what its current y coordinate so that it knows which way to turn when there is an obstacle in front. We divided the range into four distinct scenarios. If it's in the upper half where the y coordinates are larger than 1, to make sure the car does not go out of bounds, the OSV goes to y = 1.2 so that it will not need to face the obstacle in the lower half. Otherwise, the OSV goes to y = 1.8, and moves forward along the wall. Since there would only be one obstacle in one quadrant, the car does not need to worry about obstacles in the y direction when it's only moving in one quadrant. For the lower half, if its y coordinate is smaller than 0.3, which means it's way too close to the wall, it will go to 0.7 and otherwise it will go to 0.2 for the same reason explained above. After it circles around the obstacle, the car will go back to +x direction and move to the boundary between the front and the back, which is around x = 2.65. By then, OSV successfully navigated to the quadrant which only has a mission site. If the avoidance code has been activated, the OSV will adjust the y coordinate again to line up with the mission site.

Up to this point, the OSV is directly facing the mission site with nothing in between. Since the claw is in front of the car is about 0.2m away from the QR code on top of our vehicle, the OSV will continue moving till it's 0.2 m in front of the mission site. To determine the material of the object, we decided to distinguish between steel and copper using the magnetometer we installed in front. The magnetometer we use will give us the degree between it and the North. When it gets closer to steel, there will be a 10 degree drop according to our experiment. OSV will record the degree twice, once when the vehicle is done navigation and again when it successfully approached the mission site. If there is no significant change between those two readings, the OSV will consider it is made from copper.

Lastly, to measure the mass of the debris, we connected our tension sensor with the string that holds the claw. We have already recorded the mass of the claw and string, then, as we pick up the debris with the claw, the tension sensor will read the force again. The difference between those two number will be the mass of the debris. After transmitting all the data that we gathered, the mission is complete.

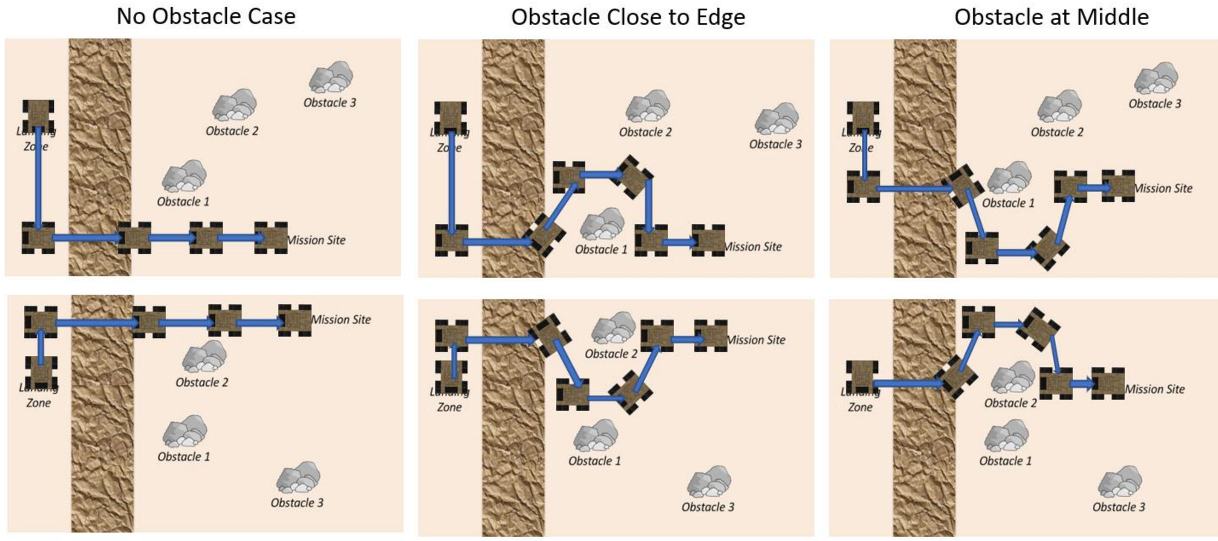


Figure 20

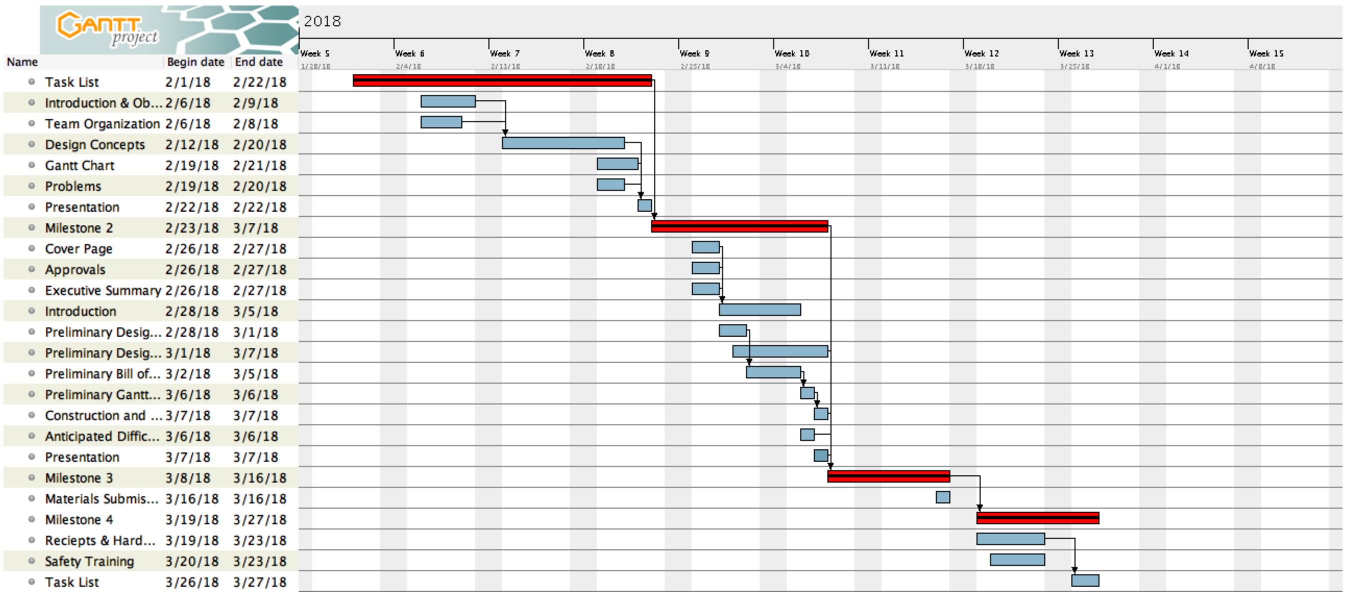
Construction Details

______We started with a 2’x4’ sheet of quarter inch plywood. We recommend though that if you can find a similar thickness plywood sheet that is smaller and not warped then do it. We cut out a 220mm x 340mm base. Then we 3D printed our motor mounts using PLA and attached them to the underside of the base using 4 6-32 x 1-¼” bolts for each motor mount. Motor mounts were attached so that when the wheels were added, their edges would be flush with the front and back of the base respectively. Power and ground were soldered onto each motor and heat shrink used to protect the leads. Then the motors were slid into the mounts and 4 holes drilled in the base so that wires from the motors could be fed topside. Once fed through those holes, hot glue was put in the holes to keep the wires from moving and shearing the motor leads. Hex adapters were put on the motor shafts and set screws tightened. Wheels were put on the hex adapters and screwed on. The Romeo Board, bread board, and H-Bridge were mounted in their respective locations using velcro. Next, three small plywood squares were cut, nailed and hot glued to the front of the base, one in the center and one on each size of it our near the wheels. A proximity sensor was hot glued onto each with its wires soldered onto it. The battery mount, location image table, crane arm, wheel, axle, and final motor mount were printed. The battery mount was attached to the underside of the OSV using the same bolts as the motor mounts. The location image table was hot glued above the Romeo Board in the back of the vehicle. The wheel was fixed at the end of the crane arm with the axel. The axel was hot glued in place. After that, the whole crane assembly was attached to the base using two of the same bolts as the motor mounts. Then, the fifth motor mount was attached at the base of the crane using four more bolts and the motor slid into it with power and ground already soldered onto it. The magnetometer was mounted out front by zip tying its wires to the crane arm. Finally, the claw was suspended using a string which ran to the crane motor that had a 3D printed spool on it with the tension stretch sensor in the middle.

Final Bill of Materials Table 2

Parts	**Manufacturer/Vendor & Model Number**	**Description**	**Price ($)**
Motors (x5)	ServoCity, #638388	65 RPM Mini Econ Gear Motor, planetary style	50
Battery	AA Portable Power Corp., #CU-J1214	14.4V 3.2Ah NiMH Battery	60
Communication module	Dfrobot, SKU: TEL00005	APC220 Communication Module	20
Wheel (x4)	Revolver/ServoCity, #82062	Revolver Robot Wheel	16
Romeo Board	Romeo/Dfrobot, SKU: DFR0004	N/A	30
Hex Shaft Wheel Adapter (x4)	ServoCity	Attaches wheel to motor shaft	16
Kill Switch Wire	Lynxmotion, #WH-01	Wire located between battery and Romeo Board	5
Magnetometer	Smakn/Amazon, #GY-273	Triple Axis Magnetometer Breakout Board	9.26
Wood Board (467500 mm^3)		Plywood base	0.24
Tires (x4)	ServoCity, #595646	Off Road Tires	32
Proximity Sensor	Banana Robotics, #HC-SR04	Ultrasonic proximity sensor	4.8
Claw	MakeBlock/RobotStop, #RB-Mab-106	MakeBlock Robot Gripper	27
Motor mount (x5)	ServoCity, #555104	Aluminum Motor Mount F	10
PLA Crane (117741.042 mm^3)		3D Printed Crane Arm	14.72
PLA Crane wheel (19142.411 mm^3)		3D Printed Wheel that will sit on the top of the crane arm and act as a pulley for the string	2.39
PLA OSV Position Tracker (64000 mm^3)		3D Printed Table that will have the location image tracker on top	8
H bridge	Qunqi C/Amazon, #MK-050	Controls direction of additional motors	6.89

Stretch Sensor	RobotStop, #RB-/ima-12	Wire with conducting terminals that changes resistance under tension	8.95
Bread Board		Creates extra ports for wiring	0
Voltage Regulator	SparkFun, #COM-12766	Modulates voltage from 14V to 12V	15
Total Cost			**336.25**



<u>Final Gantt Chart</u>

Figure 21

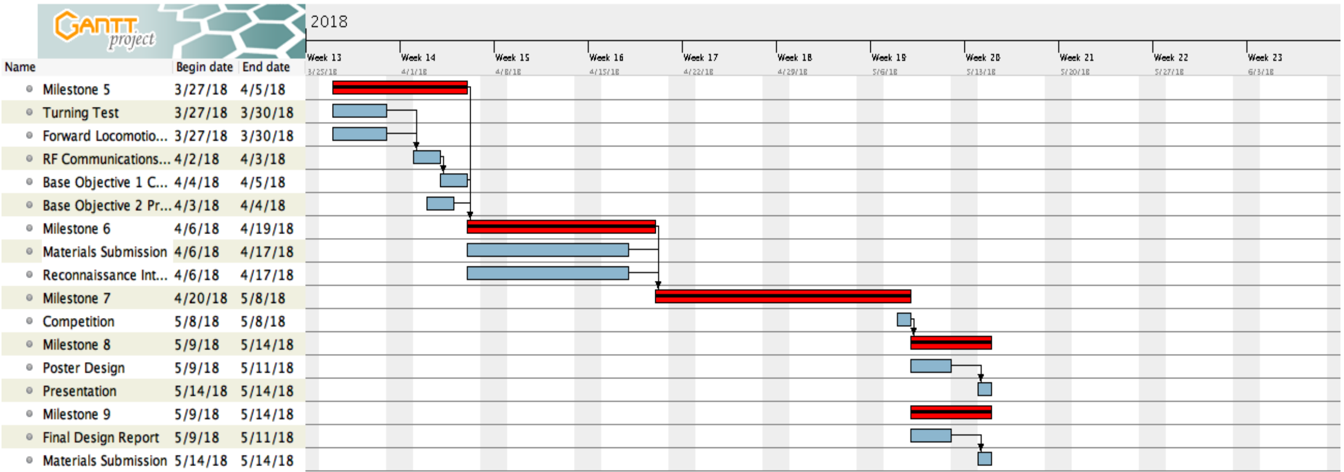


Figure 22

Product Performance and Evaluation

We would have made some design changes if we were to do this again. Overall, our vehicle worked very well. We were able to drive well on the sand, navigate the rocky terrain, and avoid obstacles. However, when we were testing picking up the material, we were able to do it with the claw, but in the arena it would be hard to orient the vehicle perfectly so that the claw was effective. Also, while the tension stretch sensor was able to get the mass to within 20g, it was not as accurate as we would have liked. Given these issues, if we had to redesign the vehicle, we would probably use some kind of hook that can be raised and lowered with a load cell at the end acting like a cantilever beam to measure the mass of the material. We would choose this because a hook will not swing in front of the vehicle like the claw did and the load cell would be a lot more accurate than the tension stretch sensor.

From a coding standpoint, we would not make any changes unless we could get better proximity sensors. We had this one idea at one point during the build phase for the OSV to try to sense obstacles from the landing zone across the rocky terrain and then find an open path by driving around the landing zone instead of driving right up to and obstacle and then avoiding it. This method showed promise in testing, but ultimately our proximity sensors were not mounted high enough and they were too cheap to reliably give us readings at that distance. If we were able to obtain better proximity sensors the next time around, we would most likely be able to simplify the control algorithm.

Electrically, the next time around we would try to find a way to manage the wires better. Towards the end of the build phase, our wiring became a kind of rat's nest. If we were to get rid of the claw and go for the hook, we could cut out the H-Bridge and all of the wires associated with that as we could operate the hook with a servo. Also we could have run the proximity sensor and magnetometer wires under the vehicle and only brought them up near their respective ports. Given the chance to design the OSV again, those are the changes we would make.

Lessons Learned

We learned many lessons throughout the course of this project. First, we learned the importance of brainstorming together because the perspective that one person has on the problem may not be the same as another. It is beneficial to hear everyone's ideas because most likely that difference in perspective will lead to a better final design because the problem will have been approached from many different angles. Another lesson we learned, was the importance of understanding one another's strengths. We were able to get a clear idea early on as to who had what skill sets which allowed us to break the team down into very effective sub groups. However, if we were to start again we would like to find more prominent roles for the members that did not come into the class with a specialized skill set as this time around it was very hard to incorporate them into some of the work. A final lesson that our group learned, was the importance of a documenting your progress and work. There were several times that we all did not remember which sensor went to which port or if the sensor took 3.3V or 5V and it was very helpful to be able to go into our documentation and check. The lessons that we learned this semester are teachings that we will take with us through the rest of our time in college and into our careers.

Minutes

2/16 - (75 minutes)

- Met each other and got to know one another a bit
- Began learning each other's strengths so that strong sub teams could be created

- Began discussing the project and design decisions that we could make

2/20 - (120 minutes)

- Split the group into their respective subteams and assigned general tasks for the semester
- Began working on MS1
- Discussed and made preliminary design decisions such as four wheel drive, differential steering, plywood base size, and made tractive effort calculations along with preliminary motor selection and propulsion design

2/21 - (45 minutes)

- Finished MS1 and came up with our team name

2/27 - (90 minutes)

- Made edits to MS1 in preparation for MS2
- Made final decisions on parts for propulsion and our sensors
- Designed our claw device/figured out how to pick up the material and measure its mass

3/6 - (90 minutes)

- Finished MS2 and finalized all of the parts that we wanted to order

3/13 - (90 minutes)

- Reviewed the good and bad of MS2
- Worked on MS3 and gave the order to start purchasing parts online so that we would have them when it came time to build the bot

No team meetings between 3/13 and 5/3 because we were in the middle of the build phase and all communication was done in class and over text

5/3 - (45 minutes)

- Divided roles for who needed to do what on the poster
- Went over everything that needed to be done before the end of the semester

5/10 - (90 minutes)

- Discussed the results of the competition
- Worked on the poster and the paper

5/13 - (90 minutes)

- Finished poster and practiced speaking roles
- Printed poster