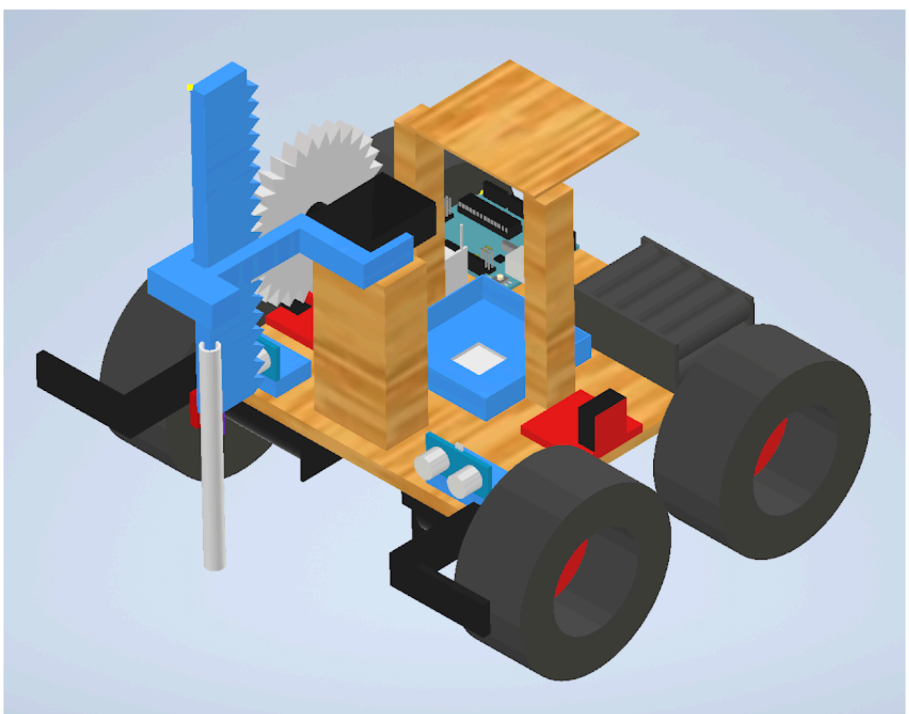
Milestone 3

Preliminary Design Report

Mike's Hard Water

ENES100 - Section 0101



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Approvals

Joseph Garris - Risk Analysis and Intentional Iteration, Preliminary Bill of Materials

Alex Holtz - Propulsion, Power, Control Algorithm

Andrew Li - Construction and Testing Plans, Task List, OSV Mission

Kaitlyn Moore - Executive Summary, Introduction, OSV Mission, Teamwork and Originality

Julianna Reese - Compatibility of Subsystems, Control Algorithm

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Brian Tinkler - Structure, Preliminary Design Drawings

Executive Summary

Our group is building an Over Sand Vehicle (OSV) to complete the Water Sampling Mission. This mission requires us to construct an autonomous vehicle that can navigate over sandy/rocky terrain, designed to simulate testing the pollution of a lake after a hazardous material spill. The OSV needs to meet the standard structural requirements as follows: be under 2.5 kg, have a 300 x 300 mm footprint, no lithium/lead acid battery technologies, no combustion engines, be able to run all systems at full power for at least 10 minutes without replenishing its energy source, be able to complete all objectives in under 5 minutes, be able to transmit and receive WiFi communications, and be controlled with an Arduino microcontroller. To complete the mission, the OSV needs to be able to perform the following tasks: navigating to within 250 mm of the water pool, measuring and transmitting the type of water (freshwater, saltwater, polluted freshwater, or polluted saltwater), measuring and transmitting the depth of the water to within 4 mm, and collecting a sample of 30-45 milliliters of water from the pool. Polluted water is dyed with deep green food coloring. After careful consideration of various design and mission approaches during numerous group meetings, we have chosen to pursue a rack and pinion arm design for our OSV. This design contains a method to propel the vehicle, a method to measure and transmit the type of water in the pool, and a method to collect a water sample. For propulsion, our plan is to use four motors, one on each of the four wheels, with large wheels that have enough traction to move over the sandy/rocky terrain. To measure the salinity and depth of the water, there will be a rack and pinion system powered by a 360-degree servo to raise and lower an arm with attached depth and salinity sensors. A hose connecting to a water pump will obtain the water sample. The output of the hose will be to a transparent basin. Underneath the basin will be a color sensor to detect the color, and thus pollution, of the water. The OSV will navigate using the Vision System to determine its location in the arena, and two ultrasonic sensors on the front to aid in avoiding obstacles. As we progress to the fabrication stage of the project, our subteams are Electronics, Coding (with sub-subsystems Sensing and Locomotion), and Structure (with sub-subsystems Materials and Chassis). Our group has just completed the Milestone 2 Preliminary Design Presentation and is currently completing Milestone 3.

Introduction

The objectives of the water sampling mission include being able to navigate our OSV to within 250 mm of the water pool, measure and transmit the type of water, measure and transmit the depth of the water (selected from 9 predetermined water levels ranging from 20 to 44 mm) to within 4 mm, and collect a sample of 30-45 milliliters of water from the pool. The four water quality types are: fresh tap water (will not be saline free), salt water (14 g/L), polluted fresh water (fresh tap water and with green food coloring), or polluted salt water (14 g/L salt/water with green food coloring). The water pool has dimensions shown in Figure 1 below. The center of the water pool is on top of the rock substrate within 50 mm of the destination, relative to the Vision System's frame of reference. The sand is at a set height 30 to 50 mm around the base of the water pool.

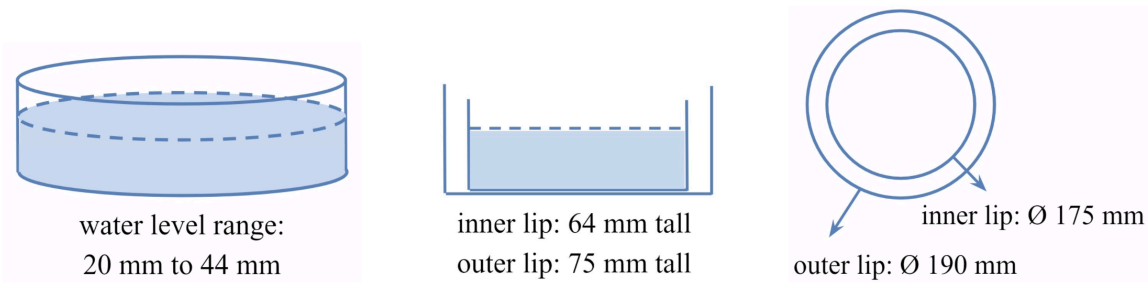

Figure 1: The image above illustrates the water sampling pool dimensions.

Figure 2: The images above depict the water sampling pool containing polluted water. The polluted water is dyed with green food coloring.

There are several product specifications for the structure, navigation/sensing, propulsion, communication, cost, mass, and safety of our OSV. The OSV mass must not exceed 2.5 kg, and the body and propulsion system must fit within a 300 x 300 mm footprint. The use of lithium based or lead acid battery technologies are prohibited, and the use of combustion engines are also prohibited. The OSV must be able to run all systems at full power for at least 10 minutes without replenishing/recharging its energy source. The OSV must be able to complete all objectives for the water sampling mission in under 5 minutes. In addition, the OSV must have an Aruco tracking marker of size between 50 x 50 mm and 100 x 100 mm with a 15 mm white border placed on the top of the vehicle, and must be able to transmit and receive wifi communications using the ESP8266 WiFi Communication Module. The OSV must be controlled entirely autonomously by an Arduino compatible microcontroller. Furthermore, safety requirements state that batteries must be operated with a mechanical kill switch at all times, and batteries that have exposed leads for recharging must be equipped with male/female Tamiya connectors at all times in order to avoid dangerous shorting. Moreover, no exposed pins, nails, razor blades, or other dangerously sharp objects are permitted on the OSV. Lastly, the total as-built replacement cost of the OSV must be less than $320.

The preliminary design of our OSV contains a 250 x 200 x 6.5 mm sanded pine plywood base with a square 75mm by 75mm hollow area in the center to reduce mass. Attached to the base are four wheels, each powered by one motor, two ultrasonic sensors, an Arduino, a tracking marker, and a rack and pinion system powering an arm. On the arm is a depth sensor, salinity sensor, and hose connected to a water pump which is located on the base. The hose output will be a transparent basin located in the hole section of the base, under which an RGB color sensor will be mounted. The two ultrasonic sensors located on the front of the OSV will aid in detecting walls and obstacles in its path. The depth sensor will enable the OSV to measure and transmit the depth of the water in the pool from 9 predetermined water levels. The salinity sensor will be made with two exposed wires, and will allow the OSV to determine whether or not the water in the pool is salty depending on whether the circuit is completed (which will only occur in the presence of ions found in salt water). The hose and water pump will allow a water sample to be collected from the pool, and the water basin will be the final location of the water sample on our OSV. The color sensor will allow the OSV to determine whether or nor the water is polluted (dyed with green food coloring), and will be located underneath the transparent water basin facing upwards to detect the color of the sample once it has been collected. The rack and pinion mechanism is powered by a servo motor, and will enable the OSV to lower the depth sensors, salinity sensor, and hose into the water pool. In doing so, the OSV will measure and transmit the depth and salinity of the water as well as collect the necessary sample.

There may be numerous issues in designing our OSV which may present challenges to our team, such as a lack of clarity in goals/objectives, lack of consideration of future challenges during the selection of products and preliminary design, and unsuitable design decisions. In order to achieve a successful design, it is important for our team as a whole to address several items, including evaluating our goals and objectives of the project, as well as establishing specific, measureable, achievable, relevant, and time-bound (SMART) goals. By following these basic guidelines for a successful design, we will encounter fewer problems throughout the remainder of the project and will likely be much more successful in accomplishing the goals we have defined for our OSV and team.

For the design of our OSV, all eight team members researched and considered benchmarking examples for the structure and sensing mechanisms that would enable the completion of all water sampling mission objectives. After discussing our proposals, we had three design options for the method of water collection: a dish, a sponge, and a pump. For the first design idea, we were inspired by the mechanism of a bucket and well, which would operate by being lowered into the water pool to collect a sample. The second design option was inspired by a previous group's design shown to us during class, which involves lowering a sponge into the water pool for it to absorb the sample. The third and final design was inspired by a fish tank water pump, as the water pump and hose system resembles those used to change the water in fish tanks. The design uses a hose connected to a water pump that would be lowered into the water pool, and the sample would be pumped into an output vessel located on the base of the OSV. In addition, we had three design options for the arm on which the depth sensor, salinity sensor, and method of water collection would be attached to: a stationary arm, an arm with one pivot-point powered by a motor, and a rack and pinion mechanism. For the first design idea, we were inspired by a wall, which would simply be a location for the sensors that would be positioned in such a way that they could complete the mission without moving. The second design option was inspired by a crane, replacing the grappling hook with a flat end for our sensor to be attached. Finally, our rack and pinion design was inspired by the rack and pinion systems of tower elevators, as the system would raise and lower the arm and its attachments into and out of the water. The final design of our OSV is shown in Figure 3.

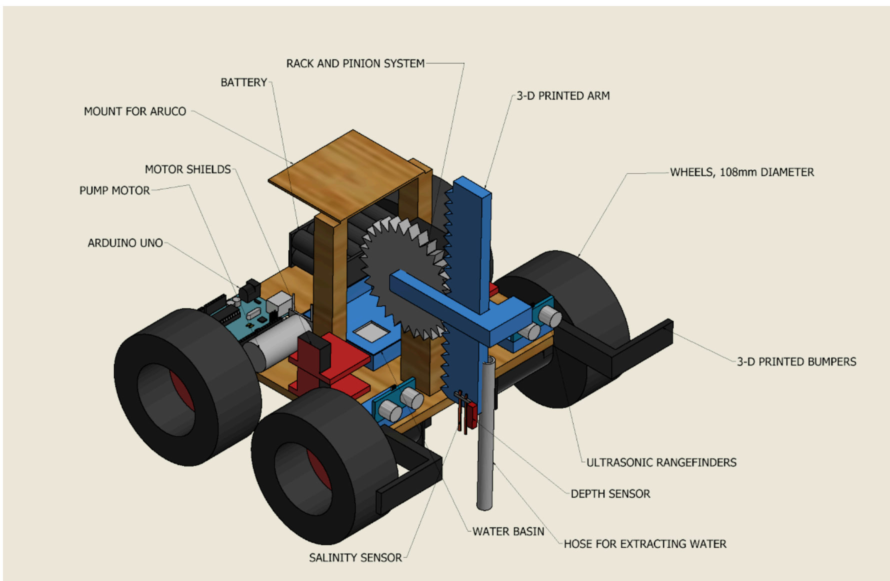

Figure 3: The engineering drawing above represents the preliminary design of our OSV. Each component is labeled.

Preliminary Design Details

I. *Structure*

Below is the front/top/right views (Figure 4) of the preliminary design of the OSV. The chassis is a rectangular shape with dimensions 250 x 200 x 6.5 mm. Also included in this section is the assembled OSV drawing (Figure 5) and mass of components (Figure 6).

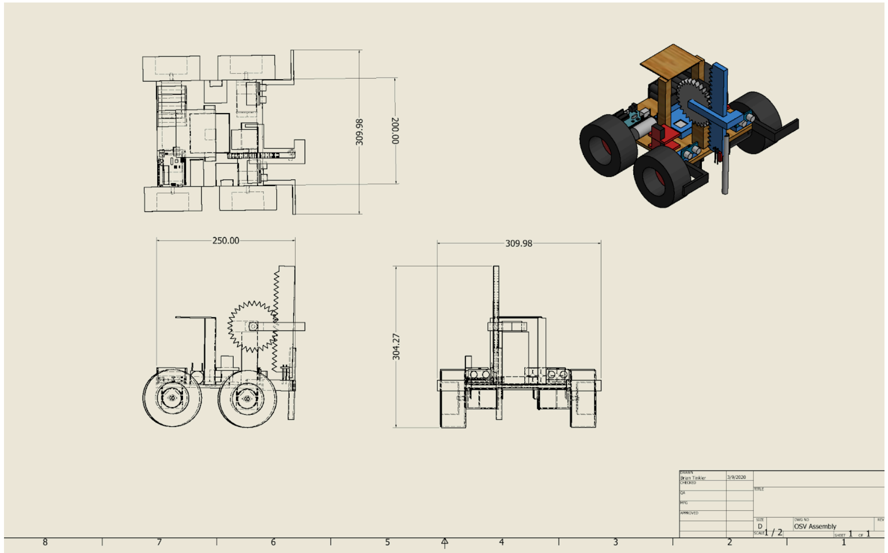

Figure 4: The 4-view engineering drawing above displays the overall dimensions of the OSV.

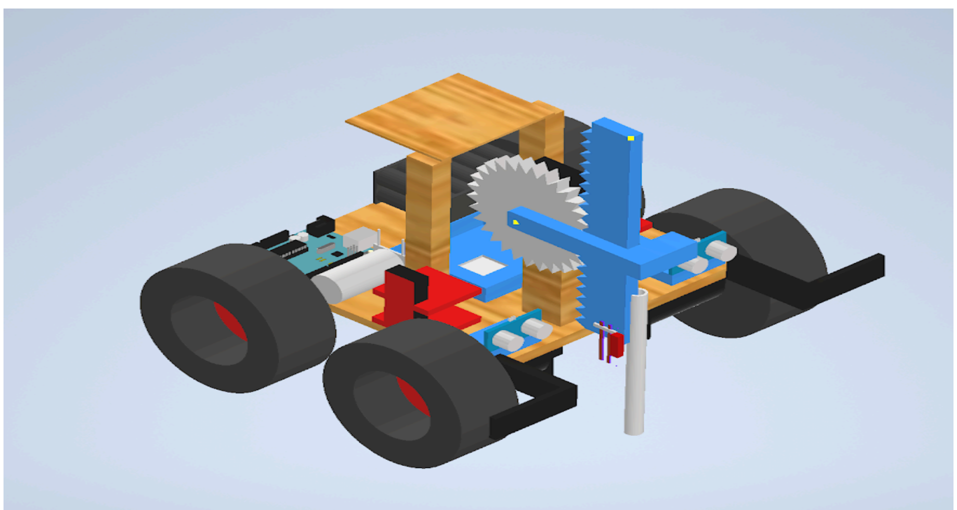

Figure 5: The above CAD model displays the full OSV design and each component's placement on the vehicle.

Part	Number of Part	Total Mass
Drive Motors	4	0.816 kg
Servo	1	0.040 kg
Motor Shield	3	0.084 kg
Battery	1	0.255 kg
Wheels	4	0.531 kg
Plywood	1	0.139 kg
Arduino	1	0.025 kg
Ultrasonic Sensor	2	0.016 kg
Peristaltic Pump	1	0.090 kg
Tubing	1	0.022 kg
Color Sensor	1	0.003 kg
Depth Sensor	1	0.018 kg
Water Collection Tank	1	0.031 kg
	Total Mass	**2.071 kg**
	Limit	**2.500 kg**

Figure 6: The above table displays the estimated masses of each of the components of the OSV, as well as the total estimated mass.

II. Propulsion

Our OSV is propelled by a 4x4 wheel and motor configuration. We chose the Goolsky 4Pcs AUSTAR AX-3009 High Performance wheels for their 108mm diameter and 46mm width. Figure 7 shows the information related to the motors we selected. Using these specifications were able to calculate the best operational speed for the motors. It is important to note that the use of motor controllers and arduino code allows for the control of the motor speed.

Model	Greartisan DC 12V 50RPM Gear Motor High Torque Electric Micro Speed Reduction Geared Motor Centric Output Shaft 37mm Diameter Gearbox
Quantity	4 (4-wheel drive)
Voltage	12V
No Load Speed	50 RPM
Stall Torque	38.9 Ncm

Figure 7: Motor Specifications

Having already decided to use 4 motors and wheels with a diameter of 108mm, a final calculation to find tM was conducted using the following formula:

CRR * Normal Force = (τM / Wheel Radius) * (# Motors)

Using a Normal force of 40N and the CRR of sand = 0.3 to introduce a safety factor into our design a ™ = 16.2 N-cm was calculated.

ω No Load 50 RPM Tstall	ω (RPM)	Torque (N - CM)	OSV Velocity (cm/s)	Time to Travel Across Arena (Minutes)
39 N-cm	0	39.0	0.0	Forever
Diameter	2.5	37.1	1.4	4.7
10.8	5	35.1	2.8	2.4
	7.5	33.2	4.2	1.6
	10	31.2	5.7	1.2
	12.5	29.3	7.1	0.9
	15	27.3	8.5	0.8
	17.5	25.4	9.9	0.7
	20	23.4	11.3	0.6
	22.5	21.5	12.7	0.5
	25	19.5	14.1	0.5
	27.5	17.6	15.6	0.4
	30	15.6	17.0	0.4
	32.5	13.7	18.4	0.4
	35	11.7	19.8	0.3
	37.5	9.8	21.2	0.3
	40	7.8	22.6	0.3
	42.5	5.9	24.0	0.3
	45	3.9	25.4	0.3
	47.5	2.0	26.9	0.2
	50 RPM	0.0	28.3	0.2

Figure 8: Using the no-load speed and stall torque, we can create a table of their relationship. From this and the ™ calculated above, we are able to select the appropriate speed.

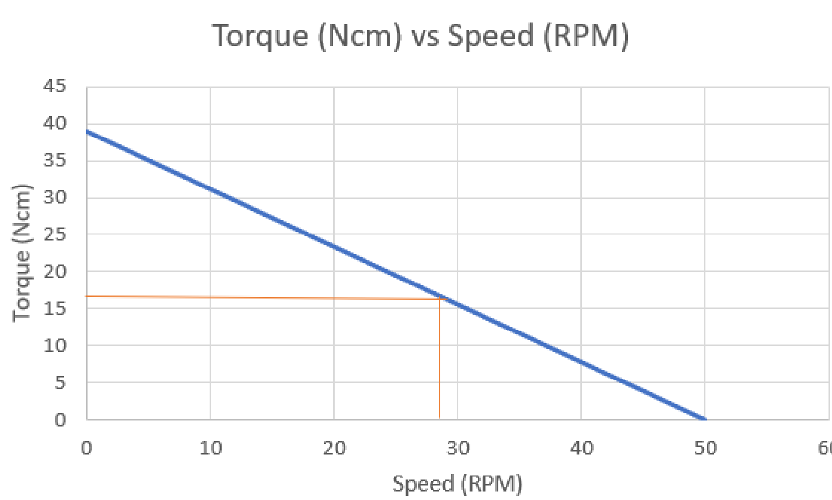

Figure 9: The above figures show the linearization of Torque vs Speed and having our tM be 16.2 N-cm a ω = 29 RPM was calculated. From this using the formula v = r * ω * (2 * π / 60) a

linear speed of v = 0.164 m/s was retrieved which corresponds to a total time to cross the arena at around 25 seconds

III. Sensors and Actuators

There will be two ultrasonic range finders placed on the front face of the OSV. They will be on the left and right sides and serve as our primary guide for navigation. The bumpers placed around the vehicle eliminate the need to place ultrasonic range finders on the sides. If the OSV happens to run into any obstacles out of direct sight, the bumpers will hit them and the OSV will continue on its original path. The ultrasonic sensors work by emitting a sound that travels through air, hits the object, and comes back. Knowing the speed of sound and the time the pulse takes to emit and come back, the sensor can calculate the distance between the OSV and the object. Each ultrasonic sensor has a ranging distance of 2 to 500 cm with a precision of 3 cm. They will be connected to analog pins on the Arduino and, as mentioned before, will operate best when detecting objects within a range of 5 to 50 cm away. They will take 5 volts each to operate. The sensors are light and inexpensive.

A color sensor will be placed beneath the clear basin that holds the water sample. It will have some small cut out of plexiglass over it to protect it from being crushed. When the water sample is in the basin, the color sensor will be able to function through the glass and the basin and detect whether there is any color present. If there is, it will know that the water is polluted. There will also be some sort of LED connected to the Arduino and the color sensor to make testing easier. If there is color detected, the LED will glow to visually communicate that the water is polluted. The group decided it was better to place the color sensor under the basin because trying to mount it on top would be difficult and present many risks, like water touching the sensor and damaging it. The color sensor will be connected to a digital pin, since we do not need to know a range of values, only if the water is polluted or not. This sensor has a low mass and costs $7.95 for one piece.

An Arduino water level sensor will be placed on the arm of the OSV, which is raised and lowered by the rack and pinion mechanism. The arm also contains the salinity sensor and the tubes from the pump, which will be lowered into the pool using the rack and pinion system described earlier. Since the sensor has to be lowered into the water, the arm is the ideal place to put it. The sensor has a "ping sensor," or ultrasonic sensor, that measures distance using sonar. It will send out a pulse and measure the time it takes for the pulse to return, similar to the ultrasonic range finder. The water level should display on the serial monitor in the Arduino code. The depth sensor will also be connected to an analog pin. This sensor is incredibly light and inexpensive.

The salinity sensor is the simplest. It will consist of two exposed wires that will be lowered into the pool using the arm and the rack and pinion system. The arm is the most practical location for the salinity sensor since it has to touch the pool. Salty water is conductive, so if the circuit completes, it will let the team know that the water has high salinity. If the circuit does not complete, the team will know the water is not salty. There will be a wire connecting the salinity sensor to a digital pin that will read the voltage.

There will be five motors, one for each wheel and another for the water pump. The drive motors will be placed under the OSV behind each wheel. This way, the motors will not interfere with the OSV's motion. The motors will be wired to the V-in pin of the Arduino. The no load speed is 50 RPM and the stall torque is 38.9 N-cm. They will be the heaviest component of the OSV. In order to vary the speed, they will be connected to motor shields. Each motor shield can hold two motors. The motor shield will take each input voltage and alter that voltage in order to translate it to a desired speed. The motors will each need 12 volts to operate at full speed. The motor controllers will need 5 volts.

Our only servo will be placed on the top of the back side of our OSV to power the rack and pinion system. The servo will be wired to one of the analog pins of the Arduino. The servo we have selected can turn a total of 360 degrees: 180 degrees forward and 180 degrees backwards. This servo will rotate a gear that will be connected to the rack and will translate rotational motion into linear motion. A servo motor functions through a series of pulses. The width of each pulse determines the angle at which it will be positioned. The servo is the second-heaviest item on the vehicle and takes 6 volts to operate. It has an operational current of 300 mA.

IV. *Power*

Our motors are each powered with 12 volts. The pump motor has its own motor controller, and the drive motors are in two parallel pairs wired through another motor controller. The controllers take digital input, which is used to determine the power given to the motors to change their speeds and directions. The motor shields themselves use 5 volts to run, which is received through a 12V to 5V regulator built into the shield. The motor shields are therefore wired to the 12V battery. The color sensor and Wi-Fi module each use 3.3V, the salinity test simply uses pin signals, and the other components use 5V. The lower voltages (3.3V and 5V) are wired through the appropriate power pins of the Arduino, and those components are wired in parallel to ensure they get the right voltages. The four motors consume 2400 mA, the pump consumes 400 mA, and the servo consumes 300 mA; this means that the battery can run for about 39 minutes. The other components are only used briefly, so when they are also used this time may decrease by a few minutes. For testing purposes, we will have 2 batteries so that we have double the battery runtime (while one battery is in use, the other will be on the charger). The mission has a maximum time of 5 minutes, therefore the battery life will not be a problem.

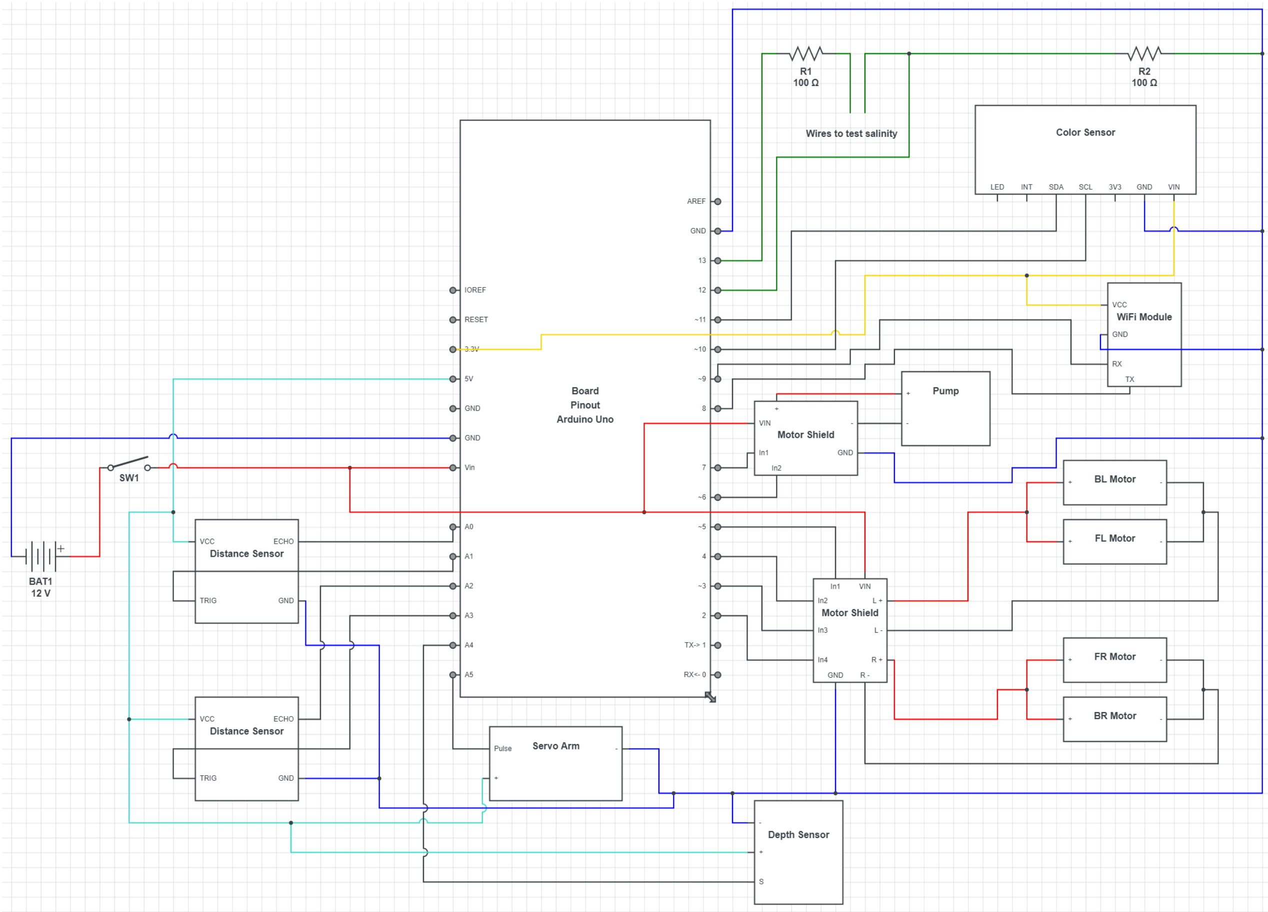

Figure 10: Electronics Schematic

V. *OSV Mission*

Our OSV will perform the water sampling mission. The mission objectives include being able to navigate our OSV to within 250 mm of the water pool, measuring and transmitting the type of water, measuring and transmitting the depth of the water (selected from 9 predetermined water levels ranging from 20 to 44 mm) to within 4 mm, and collecting a sample of 30 to 45 milliliters of water from the pool. Our mission apparatus is a rack and pinion system that will contain the water testing and collection devices. This mission apparatus will be located at the front of the OSV to simplify the collection method.

To complete the mission, most sensors and collection methods would need to be placed in the water. Initially, we had decided to have multiple moving parts for each of the sensors, however, in order to reduce complexity and cost, the team ultimately decided to have only one mission apparatus to deliver the OSV water sensors. The rack and pinion will be 3D printed to reduce weight. Currently, we have calculated the cost of the rack and pinion system plus all of the sensors and pump mechanism to be around a weight of .3 kg, well within our weight limit.

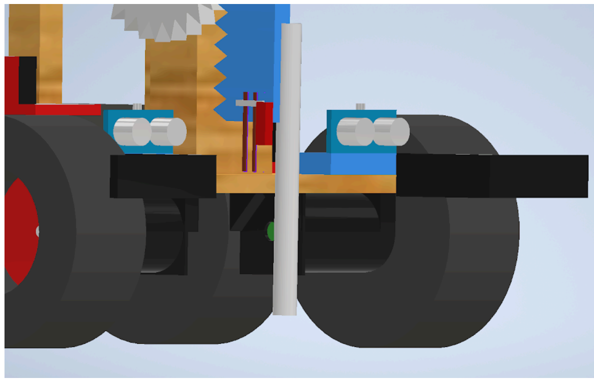

Figure 11: The CAD drawing above pictures all the sensors that will be located on the arm. In total, the salinity sensor, the depth sensor, and the tube for the pump mechanism will be located on the rack and pinion.

The actual rack and pinion will be raised and lowered by a 360 degree servo mounted to the chassis with a wooden block. This servo will rotate a gear that will be connected to the rack and will translate rotational motion into linear motion. This apparatus will be stabilized by a 3D printed part connecting the servo motor and the rack together. The power requirements of this apparatus are around 300 mA for the servo and 400 mA for the pump. The pump is 12V and will be able to be connected to the battery, however with the servo being 6V we are still deciding how to approach connecting the motor to the battery.

As for Arduino allocation, currently our electronic schematic shows that we are able to fit every device for our water mission onto the arduino. The pump will be connected to a motor shield, and the servo will be connected to the arduino directly so we can control exactly the amount of rotations to deliver the mission arm. Of the pins needed, both the color sensor and the salinity sensor will only need a Yes/No output, so only 4 of the digital pins will need to be used. The servo arm and depth sensor will both need to deliver a range of values, so they will both use a total of 2 analog pins. As for the pump, it will be connected to a motor shield connected to another digital pin. With this pin layout, the OSV mission arm will have enough pins for the Arduino Uno.

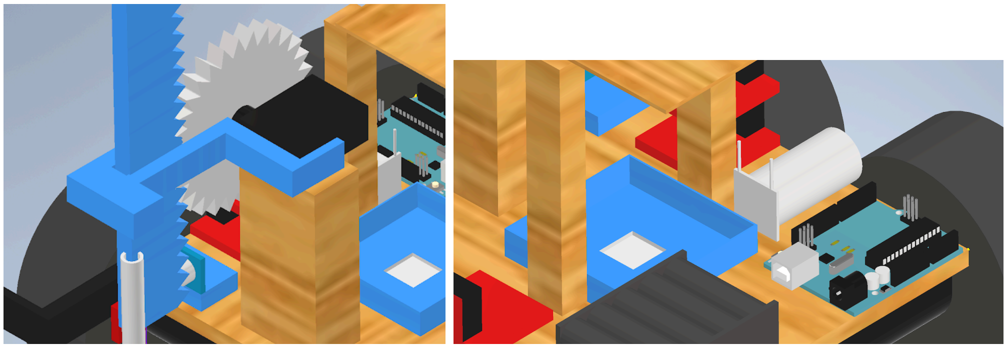

Figure 12: The figure on the left helps to visualize how the Mission Apparatus will be attached to the OSV. The figure on the right visualizes the placement of the water collection container (located as the center blue box).

The items most important to complete mission are as follows: the pump mechanism, the color sensor, the depth sensor, and salinity sensor. Ideally, once the OSV has reached the edge of the pool, the rack and pinion will lower the arm into the water. From there, the depth sensor will retrieve a reading from the water. The depth sensors only have a detection area of about 40 mm, however given the maximum depth of 44 mm and error up to 4 mm, the depth sensor should still be able to give an accurate reading. Even though there is this inherent flaw, we still decided to continue with this choice as it was a very strong choice from previous years. Once a reading has been retrieved, the salinity sensor composed of two exposed wires will begin to test the water. If the water is salty, it will be able to complete a circuit, however if the water lacks salt ions, the circuit will not be completed and we will know the water lacks salt. A previous arduino salinity sensor was decided against as it would be too expensive. This information will be relayed back to the arduino and transmitted. From here, the pump mechanism can begin to start pumping the water. On average, the pump will take 30 seconds to fully pump the sample. A color sensor located at the bottom of the collection tank will be able to tell the difference between the much darker polluted water and the clear non polluted water. From there the color sensor will relay back to the arduino whether or not the water is polluted. We decided upon this two-step pumping and detection of pollution approach after researching that the color sensor would need to be at a close distance and color detection is not always reliable. Therefore, our team decided that having a pump deliver water to an external basin on our OSV so the color sensor could read it is the most reliable choice. Finally, once the water sample has been collected, the pump will shut off and the mission will have been completed.

VI. Control Algorithm

Our strategy to navigate our OSV through the arena to the mission site has three main stages. The OSV must navigate the rocky terrain, avoid the obstacles, and arrive at the water pool. The navigation of the OSV relies on a lane system. As seen in Figure 13, there are only 3 possible lanes in which obstacles will be found, and by using this fact we can create a navigation algorithm.

Figure 14 shows a basic flow chart for navigation algorithm. First, the OSV must rotate to face forward (theta = 0). Then the OSV will move forward to traverse the rocky terrain and continue until either an obstacle is detected or the destination zone (seen in Figure 13) has been reached. In the likely case that an object is detected the OSV will switch to an adjacent lane and continue. This step is repeated until the destination zone is reached in which case the OSV can navigate directly to the water pool, as the location is known. An example of the control algorithm can be seen in Figure 13.

An edge case that may cause concern is as follows: if the OSV encounters the second obstacle and does not know where the first one was (aka did not previously encounter the obstacle), we may then change lanes in between the two obstacles. This is not an issue however, due to the fact that our OSV has a length of less than 30 cm, we have enough room to detect the obstacle and change lanes within the 0.5 m area between obstacles. In addition, the bumpers protect the wheels and ensure minimal inconvenience in the case of a collision.

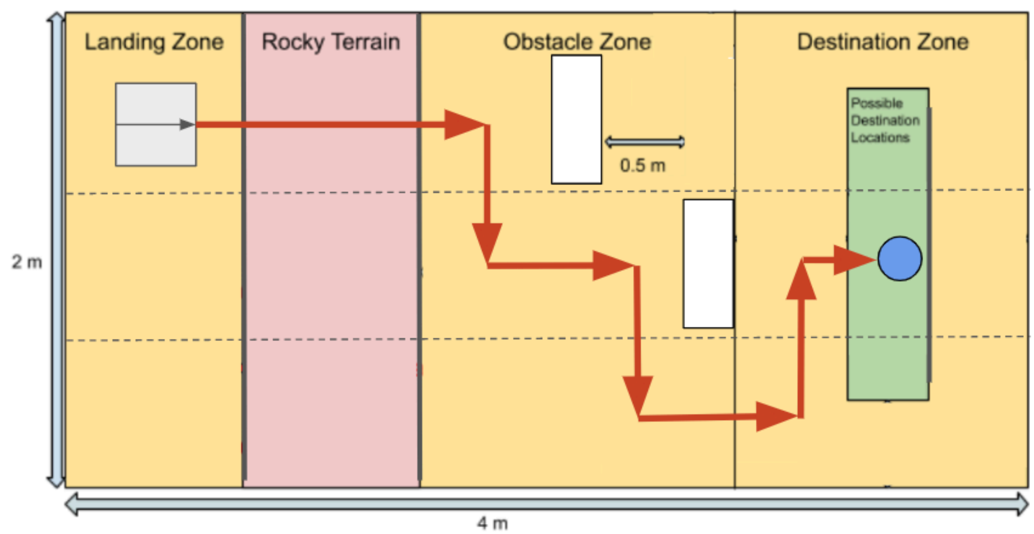

Figure 13: The images above depict the OSV arena with dotted lines representing the separation between “lanes” that are used for navigation. The red arrows show the path taken in this case.

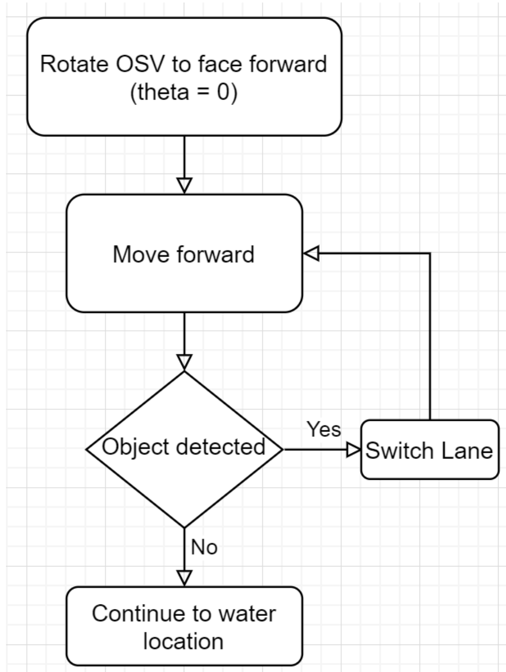

Figure 14: The images above depict a basic flow chart of the OSV control algorithm

In order to perform the necessary navigation the OSV relies on two sets of information. The OSV uses the data from the vision system which includes: location of OSV, orientation, and location of water pool. The navigation algorithm also relies on data from two ultrasonic sensors located on the front left and front right sides of the OSV, facing forward. The ultrasonic sensors are rated to have an operational range of 2 cm to 500 cm, but will most likely work best within 5 cm to 50 cm. With our system we will be looking for obstacles within 20 cm which should allow proper turning space and can be adjusted during testing. With the lane system described above, the ultrasonic sensors only need to look straight ahead, but are located on the edges of the base so that we may avoid collisions in unanticipated scenarios. Using two ultrasonic sensors also means the arduino will have enough pins available for other electronics; the ultrasonic sensors have 4 pins: VCC, trig(Input), Echo(Output), and GND.

Compatibility of Subsystems

The two ultrasonic sensors, depth sensor, and servo arm are all connected to analog pins. The other components and salinity test circuit are wired to digital pins. There are just enough pins for all the components. The motors are the heaviest, but all other components are rather light, resulting in the estimated total mass of our OSV to be under the 2.50 kg limit. The depth, salinity, and color sensors are all to be on the end of the arm, and they are not so big as to conflict with each other's placements. All other components are located on the chassis, which has ample enough room for them not to interfere with one another. Most components cost under $10 each, with the more expensive items being the $28 servo and the four drive motors that total

$66. These items leave plenty of room in the $320 budget for additional or replacement materials.

Risk Analysis and Intentional Iteration

The main issue that will arise with the salinity tester is the possibility that the circuit may complete even if in freshwater. In order to prevent a complete circuit we must test the maximum distance a circuit will complete with freshwater and compare it to that of the minimum distance that saltwater will complete a circuit. With the known information we will be able to find a range that will suffice in proper placement of the wires. If such a range does not suffice with the distance allowed by the arm, we will use the remaining money in the budget to purchase a salinity sensor. Due to the tight budget, this makes the salinity sensor a high risk item.

With the depth sensor being attached to the arm, if it is lowered too rapidly or too low the OSV runs the risk of damaging the depth sensor. In order to prevent damage to the sensor the best alternative is to run the system with a spare, as well as set the arm to a slower setting to decrease possible damage. With the extra sensor installed the OSV, we will have a backup in case of damage to the other, and will this still be able to obtain data. Also, the pack of depth sensor we decided on includes 10 pieces, so there are many backups if problems arise.

The Ultrasonic sensor may run the risk of having potential blindspots. In order to prevent damage due to blind spots, the OSV will be installed with bumpers along the edges to stop the OSV from ramming into and damaging important components on the OSV, as well as scanning the surrounding area in search for the best route to move around the obstacles.

The wheel motors, while made by the same company, will not perform in the same manner. Each motor will operate at a separate level of efficiency no matter how slight the difference. To avoid complications in the trial stages, we must test the speed and torque of each motor we install, and code so each operates in the same manner. Due to the wheel motors being key to reaching the mission site, they are a high risk system that needs to work in order to complete the mission

The color sensor may have the issue of not picking up the difference in color between polluted and non polluted water when positioned underneath the transparent water basin. This will be fixed by mounting the color sensor directly above the water basin so there are no barriers between the color sensor and the water.

The tubing is a high risk system because during the water collection process, some of the water may remain in the tube after the pump runs its initial process in the water to get the 45 mL. In order to ensure that all the 45 mL sample reaches the container, the pump will run again after being removed from the water so that air will push the remaining water in the tube into the container.

The batteries we have will only run our OSV at full power for 39 minutes, which is a fairly short amount of time. In order to ensure the OSV does not lose power during the trial and will be at maximum efficiency, we will purchase two identical batteries. While one battery is in use, the other will be charging. That way, just before the trial, we will place the fully charged battery on the OSV.

We may find that the wheels we selected may not have a great tread once they arrive, which would result in poor sand maneuverability. If the wheels have poor treads we will install treads to the outside of the wheels to create a larger surface area as well as create more traction.

The servo motor runs the risk of jamming or dislodging while moving. If the servo motor does not work, all of the subsystems for water testing will malfunction and not be able to complete the mission objectives. In order to prevent a jam, we will ensure all gears are properly filed down to ensure a smooth, clear contact between them. In addition, we will install a secure mechanism to which the servo can stay in place and move without dislodging. Since the servo motor is vital to the success of the mission, it is a high risk item.

The container used as our water basin may have an issue with being foggy or dirty, thus making it hard for the color sensor to read the color. To prevent a dirty container, we will have a clean container placed before each trial so that it cannot inhibit the ability of the color sensor.

The challenges that arise with integrating subsystems include analyzing how each system interacts with one another and analyzing how a potential issue with one system may pose a challenge to another system. For example, if the servo motor does not run properly, none of the other sub systems for water testing will work. It is important to forsee any possible errors so our group can make backup plans, and therefore have a more successful mission.

Preliminary Bill of Materials

Item	**Description**	**-Manufacturer:** **-Vendor:** **-Model Number:**	**Cost ($)**	**Mass (kg)**	**Date of Justification and Team Approval**
Goolsky 4Pcs High Performance Wheels	-Diameter: 108mm -Width: 46mm	-Austar -Amazon -AX-3009	37.00	0.13	3/12/20
Peristaltic Liquid Pump	-12V -Flow Rate 100ml/min	-INTLLAB -Amazon -606015745006	9.8	0.09	3/13/20
Greartisan DC Gear Motor	-12V -50RPM -38.9 N-cm stall torque -Output Shaft Diameter 37mm	-Greartisan -Amazon -Grearstian	66.00	0.20	3/14/20

Aceirmc HC-SR04 Ultrasonic Sensor	-5V -2-500cm detection area -3cm precision -40kHz	-Aceirmc -Amazon -N/A	14.00	0.008	3/15/20
RGB Color Sensor	-3.3-5V -3,800,000:1 dynamic range	-Adafruit -Adafruit -1334	18.60	0.003	3/16/20
XLX 10PCS Water Level Sensor Module	-3-5V -40 x 16mm detection area	-XLX -Amazon -N/A	9.00	0.02	3/17/20
Plywood	Birch	-UMD -UMD -N/A	3 *1st Free	0.14	3/18/20
Tenergy NiMH Battery Pack	-12V -2000mAh -Nickel metal hybrid	-Tenergy -Amazon -N/A	44.00	0.26	3/19/20
5 PCS L298N Motor Drive Controller Board	-5V -4 inputs -4 outputs	-DAOKI - Amazon -FBA_TS-US-078-SNL	11.80	0.03	3/20/20
Arduino UNO	-5V -14 digital I/O Pins	-Arduino -UMD -NA	0.00	0.03	3/21/20
Ziploc Square Extra Small Container - 8ct	-118 mL -Clear	-Ziploc -Target -253-01-0095	2.80	0.03	3/22/20
Silicone Tubing	-Length: 1m -Outer Diameter: 5mm -Inner diameter: 3mm	-Uxcell -Amazon -a19011600ux0208	7.20	0.02	3/23/20
High Speed Continuous Rotation Servo	-360° spinning servo motor -120RPM -50 Hz signal	-Adafruit -Adafruit -3614	2.008	0.04	3/24/20
		TOTAL	**274.00**		

Figure 15: The above table lists all materials with corresponding manufacturer, vendor, model number, description, mass, cost, and date of justification to purchase/team approval. No items have been purchased.

Teamwork and Originality

Our team structure is illustrated in Figure 16 below, and consists of the team leader, Brian, and four sub-teams. Each of the four sub-teams, Electronics, Coding, Structure, and Budget, have subteam leaders Riya, Alex, Kaitlyn, and Joseph, respectively. The members of each team are listed in Figure 16 below. Additionally, the Coding subteam has sub-subteams Sensing and Locomotion, and the Structure subteam has sub-subteams Materials and Chassis. There is a lot of overlap between different subteams, so we made sure to place members on more than one team so the various subteams can easily communicate their ideas and progression with one another.

Our team uses GroupMe, a free group messaging app, to coordinate meetings and other necessary items related to the design and construction of our OSV. Our GroupMe chat is already very active, and all team members check the chat at least once a day. In addition, we have a Google Drive folder that contains all documents related to the OSV project, which allows us to share important information and collaborate online even when we are not meeting face-to-face. We recognize that communication is vital in this project, and we believe that if we continue communicating with each other about the state of the OSV on a daily basis, we will be much more successful.

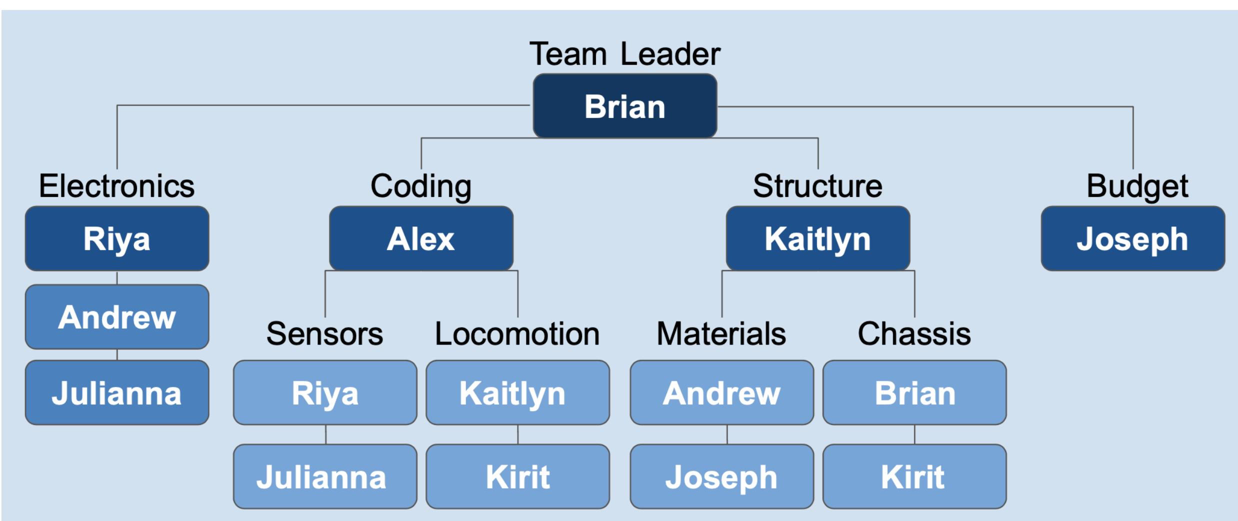

Figure 16: The tree map above displays our team structure breakdown.

The theme of our OSV/Team is inspired by the brand “Mike’s Hard Lemonade”, and we have selected the team name “Mike’s Hard Water” since we are the water sampling mission. Our team plans to showcase team spirit during the build phase and final competition through the creation of team t-shirts with our logo, shown in Figure 17. In addition, we will incorporate the colors blue, to symbolize water, and yellow, to symbolize our team logo and the hope we have for the success of our project, on our OSV using colored tapes and printed images.

Figure 17: The above image is our team logo, featuring Professor Galczynski’s face and our team name, “Mike’s Hard Water”.

The aspects of the OSV that our team is most excited about are the rack and pinion mechanism and the salinity sensor. These shared passions require overlaps among the skills of members of the team because our various backgrounds in electronics, mechanics, and CAD software are all needed to succeed in the construction and implementation of these systems. For example, we plan to create the rack and pinion system out of 3D-printed material, which means Alex, who has 3D-printed many parts before, and Brian, who has vast experience using Autodesk Inventor, must work together to design and print this part. In addition, we are creating our own salinity sensor using two exposed wires and the concept that salty water has ions that will complete the circuit. The idea of this sensor was produced by Riya, who has done extensive research on all sensing systems being used on our OSV, and Julianna, who has a background in electronics. The whole team must work together to attach this sensor, as well as the depth sensor and hose connected to the water pump, to the rack and pinion system.

Next Steps

I. <u>Gantt Chart</u>

PHASE ONE			PHASE TWO	
WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5
M T W R F	M T W R F	M T W R F	M T W R F	M T W R F

WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
1	Problem Definition					
1.1	Team Charter	entire team	2/12/20	2/17/20	5 days	100%
1.1.1	Team Availibility Survey	entire team	2/12/20	2/17/20	5 days	100%
1.1.2	Team Bonding #1	entire team	2/16/20	2/17/20	5 days	100%
1.1.3	Team Organization	entire team	2/12/20	2/24/20	12 days	100%
1.2	Identify Mission Requirements	entire team	2/12/20	2/17/20	5 days	100%
1.3	Identify Problem Constraints	entire team	2/12/20	2/17/20	5 days	100%
2	Brainstorming Ideas					
2.1	Research Existing Solutions	entire team	2/18/20	2/19/20	1 day	100%
2.2	Brainstorm Components	entire team	2/18/20	2/19/20	1 day	100%
2.2.1	Brainstorm Measuring and Transmitting of Water	Riya	2/18/2020	2/19/2020	1 day	100%
2.2.2	Brainstorm Analysis of Water Type	Joseph	2/18/2020	2/19/2020	1 day	100%
2.2.3	Brainstorm Pollution Identification	Kaitlyn	2/18/2020	2/19/2020	1 day	100%
2.2.4	Brainstorm QR Code Positioning	Julianna	2/18/2020	2/19/2020	1 day	100%
2.2.5	Brainstorm Avoiding Terrain	Kirit	2/18/2020	2/19/2020	1 day	100%
2.2.6	Brianstorm Sample Collection	Brian	2/18/2020	2/19/2020	1 day	100%
2.2.7	Brianstorm Obstacle Evasion	Andrew	2/18/2020	2/19/2020	1 day	100%
2.2.8	Brainstorm Chassis Design	entire team	2/18/2020	2/19/2020	1 day	100%
2.2.9	Brainstorm Sensor Implementation	Alex	2/18/2020	2/19/2020	1 day	100%
3	Decision-Making					
3.1	Evaluate Brainstormed Ideas for Each Category	entire team	2/19/2020	2/23/2020	4 days	100%
3.1.1	Measuring Depth of Water- discuss	Riya	2/19/2020	2/23/2020	4 days	100%
3.1.2	Measuring Pollution- discuss	Kaitlyn	2/19/2020	2/23/2020	4 days	100%
3.1.3	Collection of Sample- discuss	Brian	2/19/2020	2/23/2020	4 days	100%
3.1.4	Salinity- discuss	Joseph	2/19/2020	2/23/2020	4 days	100%
3.1.5	Terrain/QR/Obstacle- discuss	Julianna/ Andrew	2/19/2020	2/23/2020	4 days	100%
3.1.6	Sensor Implementatation- discuss	Alex	2/19/2020	2/23/2020	4 days	100%
3.1.7	Chassis Design- discuss	entire team	2/19/2020	2/23/2020	4 days	100%
3.1.8	Wheel Design- discuss	entire team	2/19/2020	2/23/2020	4 days	100%
3.1.9	Motor Design- discuss	entire team	2/19/2020	2/23/2020	4 days	100%
3.1.10	Power Source- discuss	entire team	2/19/2020	2/24/2020	5 days	100%
3.1.11	Avoiding Obstacles- discuss	Kirit	2/19/2020	2/23/2020	4 days	100%
3.2	Decision Matrix for Each Individual Design	entire team	2/19/2020	2/26/2020	7 days	100%

PHASE TWO			PHASE TWO		
WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9
M T W R F	M T W R F	M T W R F	M T W R F	M T W R F	M T W R F

WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
4	Final Designs					
4.1	Make decision for Final Design	entire team	2/26/2020	3/6/2020	12 days	90%
4.2.1	Begin Sketching Final Designs for Chassis	Brian	3/2/2020	3/9/2020	7 days	100%
4.2.2	Begin Sketching Final Designs for Wheel	Andrew	3/2/2020	3/9/2020	7 days	100%
4.2.3	Begin Sketching Final Designs for Motor	Brian	3/2/2020	3/9/2020	7 days	100%
4.2.4	Begin Sketching Final Designs for Power	Alex	3/2/2020	3/9/2020	7 days	100%
4.2.5	Review and Finalize Sketches	entire team	3/9/2020	3/10/2020	2 days	50%
4.3	Budgeting	Joseph	2/23/2020	4/30/2020	67 days	80%
4.4	Order Materials	Joseph	TBD	TBD	2 days	0%
4.5.1	Obtain and Divide Main Chassis	Andrew	3/23/2020	3/24/2020	2 days	0%
4.5.2	Attach Motors and Wheels to Main Chassis	Andrew	3/24/2020	3/26/2020	2 days	0%
4.5.3	Attach Main Power Supply and Arduino	Julianna/Alex	3/26/2020	3/27/2020	2 days	0%
4.5.4	Code Speed of the Wheels Over the Sand	Julianna/Alex	3/30/2020	4/2/2020	4 days	0%
4.5.5	3D Print Supports for U.S.R.F.	Riya	4/2/2020	4/3/2020	2 days	0%

WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
4.5.6	Attach the U.S.R.F.	Riya	4/3/2020	4/6/2020	2 days	0%
4.5.7	Attach support for QR Code	Julianna	4/6/2020	4/7/2020	2 days	0%
4.5.8	Coding for Navigation	Julianna/Alex	4/7/2020	4/13/2020	5 days	0%
4.5.9	Testing for Navigation	Alex	4/13/2020	4/20/2020	6 days	0%
4.5.10	3d Print water collection arm	Andrew	4/20/2020	4/21/2020	2 days	0%
	Attach Water Collection arm	Andrew	4/20/2020	4/21/2020	2 days	0%
4.5.11	Set up the salinity testers to the Arduino	Riya	4/20/2020	4/21/2020	2 days	0%
5	Construction					
5.1.1	Implement depth sensor	Andrew	4/22/2020	4/23/2020	2 days	0%
5.1.2	Implement water collection device	Andrew	4/22/2020	4/23/2020	2 days	0%
5.1.3	Implement color sensor	Kaitlyn	4/22/2020	4/23/2020	2 days	0%
5.1.4	Implement communication device		4/22/2020	4/23/2020	2 days	0%

WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
6	Initial Testing					
6.1	Test salinity of different levels of salt water	Julianna	4/23/2020	5/7/2020	14 days	0%
6.2	Test that color sensor picks up changes of polluted vs. fresh water	Kaitlyn	4/23/2020	5/7/2020	14 days	0%
6.3	Test depth sensor at different water levels	Riya	4/23/2020	5/7/2020	14 days	0%
6.4	Test that water collection gets at least 40 mL	Brian	4/23/2020	5/7/2020	14 days	0%
6.5	Test that the communication center picks up data from all sensors	Andrew	4/23/2020	5/7/2020	14 days	0%
6.6	First test run with all implimentions	entire team	5/7/2020	5/8/2020	2 days	0%
7	Iterations					
7.1	Take note of all problems with first test	entire team	4/23/2020	5/7/2020	14 days	0%
7.2	Brainstorm issues	entire team	4/23/2020	5/7/2020	14 days	0%
7.3	Solutions for issues	entire team	4/23/2020	5/7/2020	14 days	0%
7.4	Impliment solutions	entire team	4/23/2020	5/7/2020	14 days	0%
8	Final Testing					
8.1	Final Test Run	entire team	4/29/2020	5/11/2020	12 days	0%
8.2	Class run	entire team	5/12/2020	5/12/2020	1 day	0%

II. *Construction and Testing*

Over the past week the team has finalized the OSV design and are now working to transition into the build phase. This involves ordering and obtaining all parts necessary, as well as building and testing of the OSV mission objectives. Week 8 to Week 12, or 4 weeks of allocated time, is currently designated to completion and initial testing of the OSV design. We plan to build the OSV in seperate parts, to help isolate issues and minimize complication of risk identification. As the team confirms that a certain part is working, OSV parts will be attached to the main chassis in our construction phase. These tasks will be completed by both the Electronics and Structure subteams as they work jointly to build the OSV main body and implement the various sensors onto the arm. During this time the coding subteam will be making and testing code on the individual sensors and locomotion of the OSV, insuring compatibility and feasibility of our design. Finally, as the OSV finishes construction, we have allocated 3 weeks of testing divided into “Initial Testing”, “Iterations”, and “Final Testing” in which during “Initial Testing” any main issues can be identified, then “Iterations” can be brainstormed and discussed, and finally "Final Testing" on the iterations can be implemented and tested. This is a fluid process and we did not feel it appropriate to designate a specific time to each testing phase and identification of issues can be staggered as we solve problems. Initial testing will be handled by those who are designated to their specific task, but both interactions and final testing will be done as a group. Lastly, the class run will be the time in which the team views all of their hard work culminated into a working OSV.

III. Task List

Task List for Week 1 of Build Phase

Task	**W.B.S Number**	**Designation**	**Start Date**	**Complete By Date**	**Total Time**
Order Materials	4.4	Joseph Garris	TBD	TBD	TBD *Team was advised not to order materials
Obtain and Designate Chassis	4.5.1	Andrew Li	3/23/20	3/24/20	2 Days
3D Print Motor Mounts/ Attach Motors and Wheels	4.5.2	Andrew Li	3/24/20	3/26/20	2 Days
Attach Power and Arduino	4.5.3	Julianna Reese Alex Holtz	3/26/20	3/27/20	2 days
Begin Coding Speed of OSV	4.5.4	Julianna Reese Alex Holtz	3/30/20	4/2/20	4 days