# Beacon and Obstacle Navigation for an Autonomous Rover

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## Abstract

We investigated the problem of constructing a robot that can navigate around obstacles towards a beacon. The obstacle course is random, yet the beacon and types of obstacles are the same. Sensors must detect walls, holes, and large objects. The robot itself must be able to traverse most types of terrain and be sturdy and reliable. To solve the current problem, we created several designs to implement and use several sensors to solve the navigate. We then made mounts and schematics for each sensor so they may mount on the robot. The robot perform each individual challenge with task with reliability. For the future of the project, if it were to continue, would bring all these aspects into play so the robot can be completed.


## 1 Overview of the Mechanics In Space Rovers and Our Challenge

Robotics will always be the main way new frontiers will be explored (Yamauchi). The creation of robust chassis and dependable sensors is vital for the exploration of foreign planets as it is very hard for humans to retrieve them back. The overview presented will discuss the importance of the methods used to accomplish space exploration.

The challenge presented to us comes from Adams State University and NASA's Colorado Space Grant Consortium. The autonomous (without human intervention) robot must drive through a variety of terrains with obstacles, such as boxes, to hinder its path and must be guided by a beacon placed at a key location in the arena. The robot must stay on the ground,  have a 500$ budget, and be under 4 kilograms. This challenge is meant to simulate what is necessary in engineering a robot that is built to survive in extraterrestrial conditions.

The robot's design is modeled to be robust and must be ready to withstand all scenarios and stresses in space. Taking this into account, we had to put the robot in several scenarios and a diverse set of stresses to accurately predict the functionality of each design.  With some designs not even making it to prototyping, we had to be selective in the final build.

The robot will be faced with many problems, such as being flip over; therefore the robot has one chance before it leaves Earth forever. To prevent this from happening, we had to add sensors.  There were a variety of sensors, such as infrared, ultrasonics, or momentary sensors (bumpers). For the robot to be aware of its surroundings we had to consider the pro and cons of each sensor.

The chassis was built to last as well as accommodate the sensors. Using a pre-built model from the project LAZARUS made by UNC ALUMNUS Rob Shiely, we had the ability to use a pre-made chassis for the sensors. This was decided upon because it moved the focus of our build to the sensors instead of the chassis itself. The sensors were made to accommodate to the chassis so the robot could better meet the challenge.

Along with mechanical work the team must have good communication so that no one is lost when constructing the robot. We must document and record all the ideas precisely so that others may understand what we have done. We do this by having team-specific notebook where ideas and prototypes are put along with the materials and code needed. We must also pitch in ideas as we are always looking for new ways to upgrade the robot. Communication is key when working with a group because everyone must be on the same page.

The goal is reliability over variation, and the plan to make sure all parts are working as intended. The rover is to be tested as if it were in rough terrain and accommodations must be made so that the robot functions as planned.

## 2 Literature Review

As space travel has already been done, we can collect data and methods used by others to help our efforts. The project can be broken down to three main sections: software, hardware, and documentation (Sheily). With the help of the team, the robot can reach all these aspects.

The software is left up to artificial intelligence (AI) which is the ability to interact with the environment around the machine However, AI can also sense the environment around it and complete actions according to the conditions (Nolfi).

As for the hardware we must agree upon a design for each section of the robot. The process which we go through is used by several companies and is proven to work. First, all designs are competitively selected through technical evaluation. Proposals must demonstrate that the designs is reasonably mature, addresses mission needs, lives within mission constraints, and can be made/designed within the set deadline (Volpe). Using these guidelines we can build efficiently without wasting time with designs that are not compatible. As for the build we evaluated several designs used by other teams working on it. To venture through terrain unknown to us we must create on board algorithms for estimation of the rover position, estimation of the surrounding terrain , and navigation decision making for driving to the goal in a safe and more optimal manner (Volpe). To mount the sensors we borrowed a robot from the LAZARUS project, a goal of hardware development to create reliable platforms capable of handling a variety of experiments and physical environments while maintaining intuitive, operator-friendly design layout (Sheily).

To document the project, we decided to make a notebook that will contain daily journals and ideas, as well as contain the MSDS (Material safety data sheet) and the BOM (Bill of Materials). Documentation, involves setting standards for maintaining a comprehensive record of all research conducted ( Shiely 3). The team wants to make sure that all people can understand the processes we went through to accomplish this goal so that we may recreate it again with less effort.

## 3 Materials

The planning, designing, and building of the robot requires many tools and materials. The MouseBot contains a Arduino Uno connected to a motor controller. These act as the brain where we upload code as well as plug electronic sensors in. The chassis and the wheels to move the robot around. To design mounts for the robot we used CREO PARAMETRIC 2.0 as a 3D CAD software (computer aided design). To make these designs become reality we used a MakerBot Replicator 2 as our 3D printer, which prints by adding a layer of melted plastic until it forms the desired shape. Several workshop tools, like hand drills, files, vice grip, jack, calipers, and hammers, were used to adjust the holes and shape of the mounts. The senses of the robot were represented by an ultrasonic and limit switch.

## 4 Methods

The methods used in the creation of the robot followed a design process (shown in writing 4.2) that helped organize the process of each individual part. What we decided was important was the area in front of the robot in relation to height, and in relation to walls. Knowing the height of the area in front of robot is very important because of the problem of falling, high centering, and flipping over. Knowing what was directly in front is also important because the robot must not get stuck on a wall driving into it. All mounts were created using Creo 2.0 and then exporting the model into a 3d printer (MakerBot Replicator 2) using PLA plastic with a 15% infill (not solid).

*MouseBot Chassis (Figure 1.)*

The chassis was used from the LAZARUS project and included motors and gearboxes. As well as the switches to turn the motors off and on. What we modified was the metal top so that it may have holes to accommodate our sensors. The chassis is used because of the need for movement and control for the robot as well as being the base on which the sensors are to be mounted. With its wheels and motor controller, the robot can maneuver around a variety of rough terrain. The front and back of the robot are angled inward (70 degrees) so the design of the mounts has to include a triangle and the sides are angled at a 45 degree relative to the sides (Figure 1) . The angles present on the chassis must be included into the mount designs as it must be strong enough so that the mounts can take trauma. The inside of the robot also provide a copious amount of space for electronics to fit in such as the Arduino Uno as well as a printed circuit board.

*Ultrasonic (also named parallax ping sensor) Mount  ((Figure 2.)*

The ultrasonic sensor was installed because the robot needed a way of detecting topography.  It works by sending a high pitched sound and measuring the difference when it bounces back. The ultrasonic was put out in front so that it could not cross interfere with itself and to make sure the robot can stop once the ultrasonic found a point where the robot cannot pass. The range the robot can drive through is between 3.5 inches and 4.5 inches, so the ultrasonic has to measure this constantly to make sure the robot does not fail (Figure 3.) . Slots were made in the back so it could be adjustable with the ability to slide in and out.

*Limit Switches Mounts (Figure 4.)*

The limit switches were installed because the robot needed a way of detecting obstacles. They work by a spring loaded trigger that either makes or breaks a circuit. Two were implemented because we needed to know if the obstacle was to the left, to the right, or in the center so that the robot can turn accordingly. It was built sturdy with more mass than the other mount so that it can absorb most of the shock of driving into a wall as these mounts were to be used a mechanical stops. They were also digital stops telling the robot there is a wall in front. Long bolts were used to mount the limit switches as low as 1.5 inches of the ground so the robot can detect if there is any obstacle lower than the center of the wheels (Figure 5.). Slots were also used so that it adjustable but were angled due to the way it is mounted.

*Electronics*

The electronics had to planned along the way making sure it made logical sense. The arduino uno was capable of analog in, and digital outputs and inputs. We only got to use the digital pins for the sensors. Simple soldering was done to connect the leads into the arduino (soldering the tips). For the limit switches a pull up resistor was made for both using a small printed circuit board. The leads for the ultrasonic sensor were solder on then using the instructions on the ultrasonic, connected accordingly.

*Design Process*

Every idea had to through a process to make sure it could achieve its goal. The first step was to get the idea for a mount. Ideas came from the need to have spatial awareness for the robot, so current rovers designs were evaluated to see what each sensor did. The challenge was broken down to manageable pieces, each with their own tasks to accomplish (i.e. how to not flip over) and we evaluate each one and decided on a plan of action. A whiteboard drawing was made so that other teammates could pitch in their ideas. Once it matured we then modeled it in CREO and attached it to the robot to see how it would function. We then refined the idea and present it to the team, which then discussed if it was acceptable. If it waS declined then we archived the progress done so that if we were to revisit it we would not need to make the same tests. If it passes then the print would be exported, made, and installed onto the robot.

*Design Notebook*

Every idea we had was put into a notebook along with the planned specifications. The notebook contained a detailed explanation on the purpose of each design, were it would be put, and the general shape. Along with the purpose we recorded the materials need to build this object. Then we observed points of failure that could occur when using the item evaluating if it would not work. The electronics were sketch alongside. Programming involvement was also crucial if we were to bring all aspects of the robot together.

## 5 Results

The robot is running and is currently driving as intended, with correct timing for the 45 degree and 90 degree turns. As soon as it is turned on, it can start driving and continue until it hits a wall and then it backs up and turns, confirming the limit switches work . It can navigate using the walls yet the ultrasonic sensors is currently not being used (due to technical issues). The robot will occasionally get stuck into corners due to the nature of the code, yet code is being written to solve the problem. The mounts are holding up to the trauma with no visible signs of being broken. The robot is currently not set up to use the beacon, but the path navigation for beacon exists.

## 6 Discussion

The robot has the ability to perform the tasks given by the challenge. The robot itself meets all the requirements for the task. The sensors mounted have the capability to run through the obstacle course. The simple test perform showed the things we could do with the sensors installed. The limit switches are working and sensing walls on both sides, and the ultrasonic sensor is ready to be integrated. The mounts are experiencing some trauma as predicted but they are not breaking. The shell of a functional robot has been made.

The navigation works as planned, yet we are continuing to find areas where the logic can be improved. It can go through obstacle navigation and beacon navigation, but as of now they are separate. The extensions of the limit switches can bend into one another and cause a false positive for a wall. We are devising new ways this can be corrected. Although this shows the idea for the limit switches work, we need a better design for the extensions.

Electronics are working, yet problems are prevalent . The ultrasonic sensor is giving false positives and must be replace. The chassis is good for spreading the trauma around the body and occasionally knock a wire out of place, but as we resolder some connections this is becoming less frequent. The electronics are holding up.

The robot has the potential to do the obstacle course with the beacon, yet lacks reliability. To continue with the project would require the robot to have more solid build to better the robot in all aspects

## 7 Conclusion

The robot has become a base for which many sensors and programming can be incorporated. Much like the LAZARUS project, this Mousebot has become a building block for which we can program better code so that it may become a more advance maze-solving, beacon-following rover. What our team contributed was the use of our designs to better the robot’s performance in an obstacle course. The electronics was improved so that it could accommodate a variety of sensors. We also documented every piece by modeling in 3D so that others may know exactly what we did. Also both the ultrasonic and the limit switch mounts so that others may use them for future. The purpose of the project was to complete the challenge and to further move the robotics program at UNC and it has been achieved.

## 8 Acknowledgments

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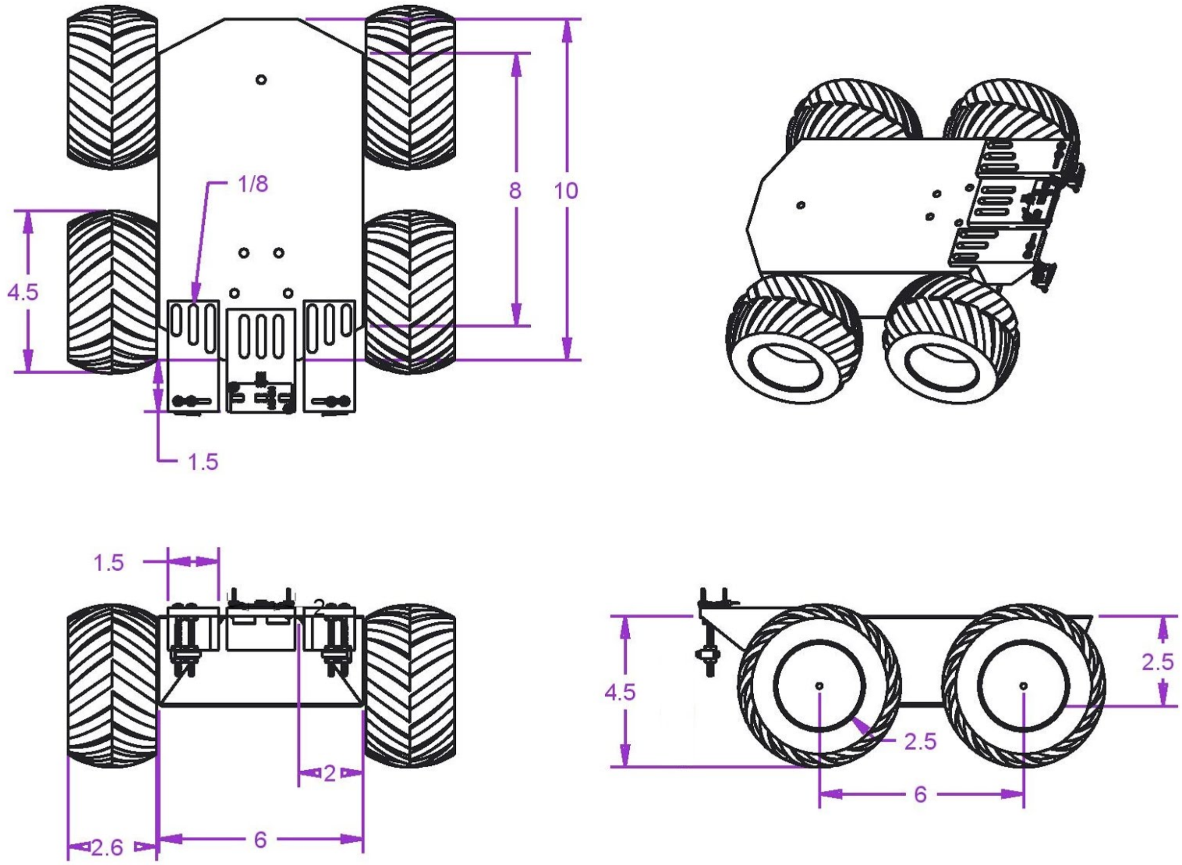
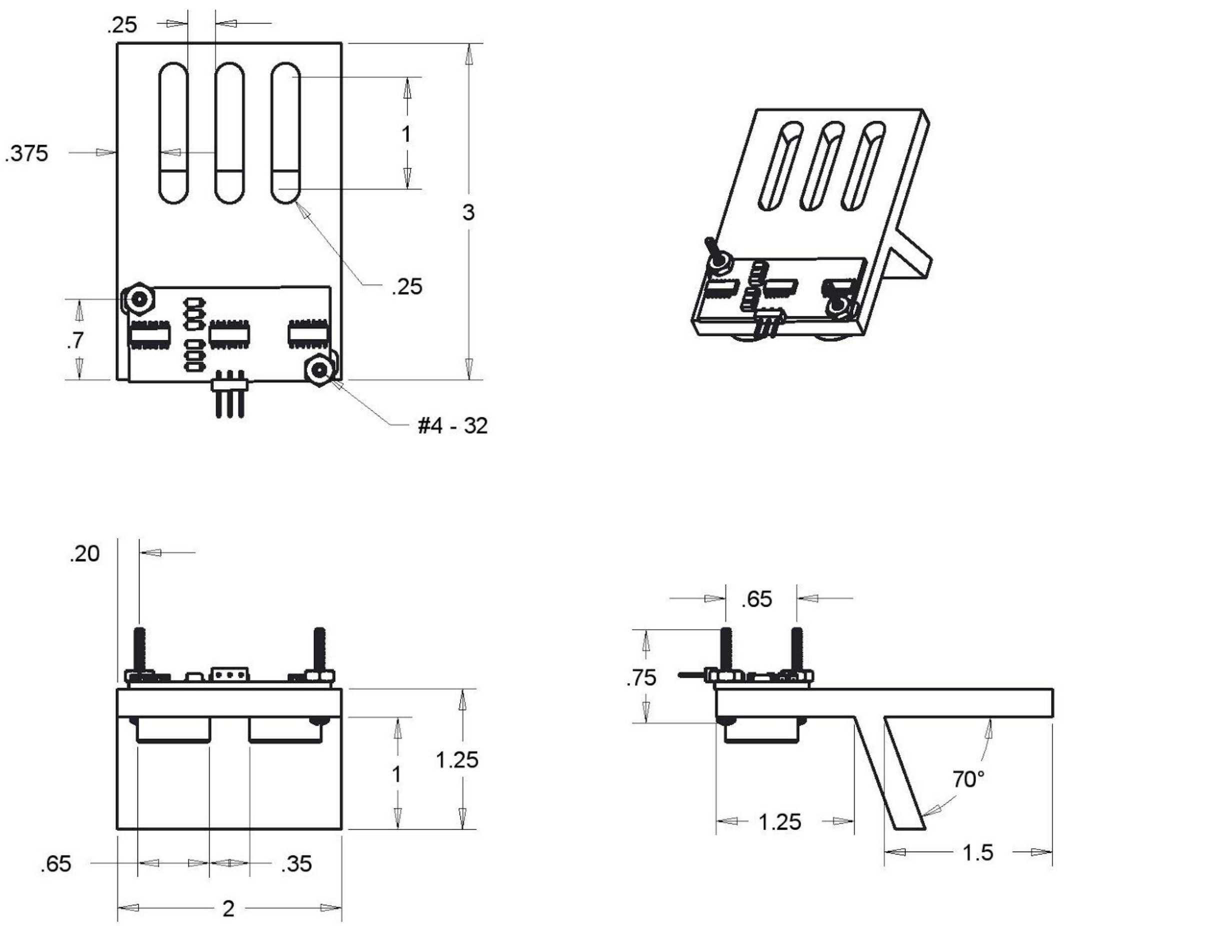
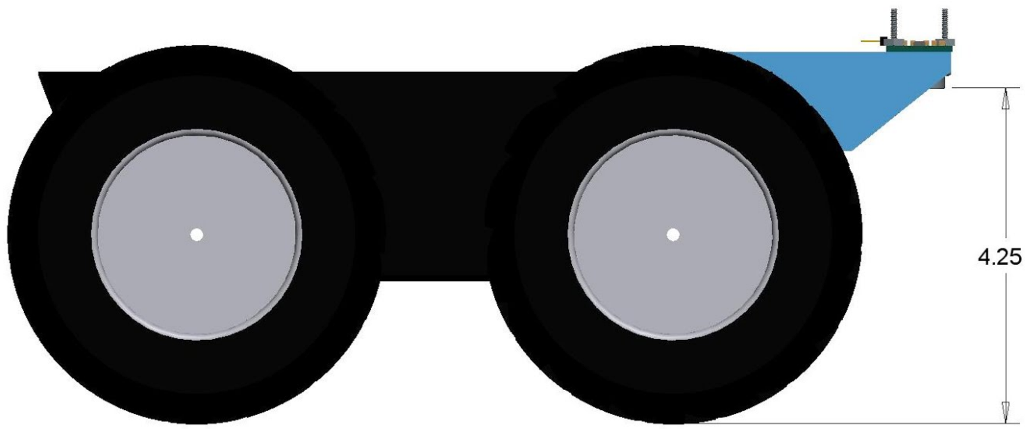
# 8 Figures



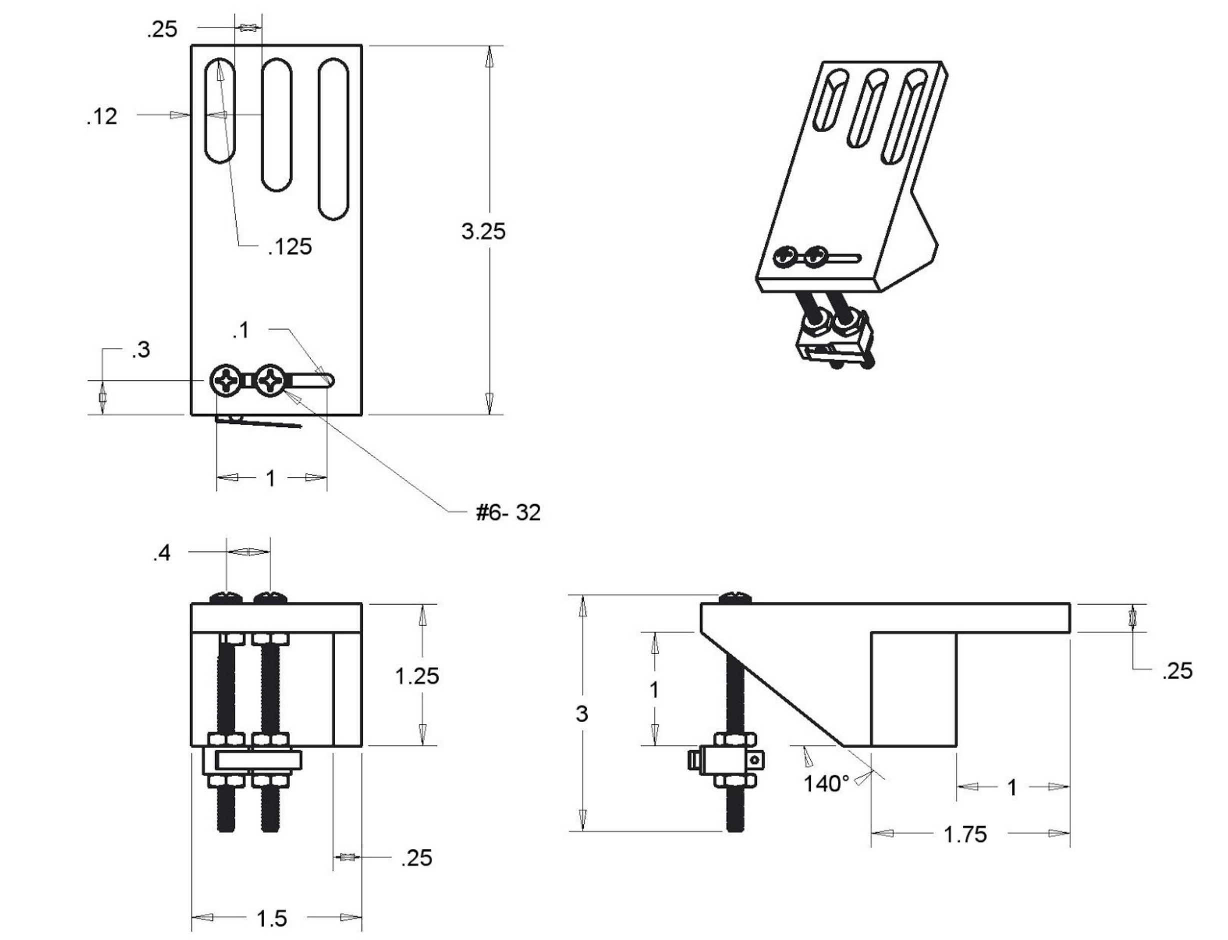

(Figure 1) Our final version of the robot. With the chassis from the LAZARUS projects as well as 3 sensors in front (from left to right)(Limit switch, Ultrasonic, Limit Switch) The mounts use the angle in front to mount. The limit switches are mechanical stops for physically stopping the robot, and digital stops for the robot. The ultrasonic is meant to measure topography in front of the robot.



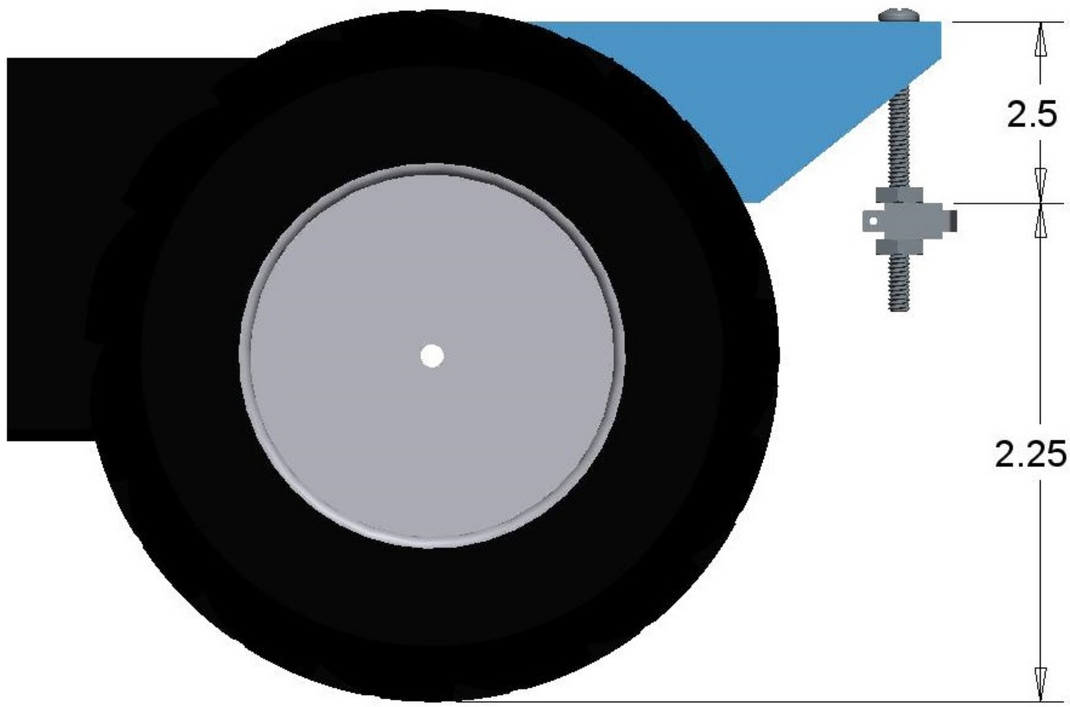

(Figure 2) Ultrasonic (also parallax ping sensor) Mount . Mounted in the front (hence the 70 degree angle) it detects the topography of the area in front of the robot. It sends a high pitched sound using one head and receives the sound in the other. Using a #4 - 32 screw for the ultrasonic sensor to be kept in place facing towards the ground. The slots are their for adjustability. Uses PLA plastic with a 15% infill (not solid)




(Figure 3) The height of the ultrasonic sensor from the ground, as well as showing where it will be mounted. to prevent high centering we must make sure the robot receives inches greater than 3.5 but less than 4.5 due to the ability of their being a hole.




(Figure 4) LIMIT SWITCH NOT TO SCALE 1 of the 2 limit switch mount. On either side (mirrored) the limit switch mount is required to have a angle so it can mount on. Used to detect walls (or big objects) as well as physically stop the robot. It has a slots for an adjustable side to side and a big screw so it can move up and down. Built to be thicker so it can absorb the trauma when moving into a wall. Uses PLA plastic with a 15% infill (not solid).




(Figure 5) DIMENSIONS NOT TO SCALE The height at which each limit switch will be at. Where it will be mounted. Another prevention to high centering as it will catch anything before the ultrasonic detects it. It may be modified.

## 9 Work Cited

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