The IceBreakers

Team 1176: Project "Off the Grid" Notebook

Little Rock BEST Robotics 2019

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Ice Breakers

The IceBreakers is a school club at Columbia Christian School competing for the third time in the BEST Robotics competition. The club consists of students from grades 9-12, teachers covering various subjects, mentors with different professional backgrounds, and various supporters. Columbia Christian School is led by the administrator, Ted Waller, to improve academically in all subjects and to provide a firm education for students.

Objective

Each team faces the task of designing and constructing a robot that is capable of reconnecting fallen power lines and replacing damaged underground wires during high-risk situations, among other tasks. Each robot will be required to be contained within a 24-square-inch box and can only weigh 24 pounds. Robots that exceed these limits will be disqualified. To earn points at the competition, the students' robot will be required to reattach power lines that have been downed due to the natural disaster. There will also be garbage on the roads that the robot may remove in order to earn points. An autonomous round will also take place, in which students will program the robot to move along a track that will be read with infrared sensors. Each round will last 3 minutes and be played with four teams, one at each game station.

Summary

The Columbia Christian School IceBreakers began the process of designing and fabricating "Kelvin" by using the engineering process, available technology, web-site design,

and the development of a robotics notebook for the Little Rock Hub competition *Off The Grid* held on November 2, 2019.

The competition is an intense six-week robotics competition for high school students. Students are given materials and a theme and are then asked to build a robot within the given time. At the end of six weeks, the students take the creations to Little Rock to compete. This competition is designed to promote math and science and to encourage the participating students to pursue technology-based careers. For 2019's game, the objective is to design a robot that can take the place of linemen during high-risk situations, and get the power back on in the event of a natural disaster.

The robot will continue to progress and evolve through out the competition. Students will use and analyze the design and engineering process to continue robot development. The students will use the trial and error process, as well as discuss and analyze the proper strategies for robot design.

After qualifying for the regional competition in Dallas, Texas, the IceBreakers started working on improvements to the robot in order to compete on the regional level. The IceBreakers continued to use available technology and resources to construct a robot for the Texas BEST UT Dallas competition held on December 5, 2019.

Research Paper

Help from Machines

There are several benefits of machines being used in place of members of a workforce at the sight of a disaster. From clearing rubble, repairing power lines, or simply gathering an overall view of an area, the use of machines can replace workers or volunteers in several high-risk situations. Just like how there are firefighters and electricians each step of the process of regenerating a civilization requires a uniquely designed machine.

Ice Storm of 2000

One of the most well known natural disasters in recent Arkansas history is the ice storm of 2000. This storm had an incredible impact on as many as fifteen counties in the southern area of Arkansas, from roads being littered with electrical wires to tree branches up to six inches in diameter having fallen. Power was initially lost on December 15. Depending on the area, citizens had no electricity from anywhere from two days up to two weeks. Two witnesses from Columbia County were interviewed about their experience. One witness stated that he couldn't even see his lawn through the tree branches on the ground. He also said that if drones had been used during the cleanup, the process would have been much faster and simpler. One of the major issues that were created by the storm was the lack of food. Grocery stores such as Walmart and Brookshire's could not restock their food supply since the roads were blocked after a few days. A large number of citizens went without receiving their weekly amount of food, in addition to frozen foods having thawed in refrigerators due to the lack of electricity. After the storm passed, the grueling process of cleaning miles of land from fallen tree branches, fallen wires, and ice began. The process of rebuilding southern Arkansas and eastern Texas lasted for almost six months due to the disadvantage of the ground being covered in over an inch of solid ice and the massive amount of debris. There was also a massive risk of more branches falling, or a fallen wire still being active.

Linemen

Linemen are most often workers that repair fallen electrical wires. Unfortunately, taking the position of a lineman includes many risks, such as falling to one's death, being crushed by rotten poles, and being electrocuted by a live wire. A lineman from the 2000 ice storm was interviewed about his experience. He explained that one of the main materials that the linemen were required to remove were fallen tree branches. The majority of the trees that inhabit Arkansas are pine trees, which become very brittle during cold weather, and with ice forming constantly on the branches, snapping of the branches was extremely likely. This would commonly cause a wire to snap. Fortunately, with the proper tools, this position can be completely operated. If a machine was manufactured that was able to scan fallen wires for electric charges, replace rotten poles with sturdy ones accurately, and reconnect fallen wires, then many deaths could be prevented. One possible solution is for a machine that could scan wires for electrical charges, outstretch an extendable arm that could reconnect wires to the standoffs, and conduct the proper tests to check the strength of the pole and confirm that the pole has not rotted. Another issue is replacing damaged underground wires. A plausible solution to this matter is to construct a machine that could scan the ground where the wire is located to determine the exact depth of the wire. The machine should also be able to uncover the wire and scan the wire for electrical charges to ensure that the wire is absolutely safe for the crew to manage the wire. Another machine that could be of great use is a drone. Drones could reduce the time taken to search for victims trapped under debris.

Food Shortage

The main worry during any natural disaster is a food shortage. The average human can go about three weeks without food, and three days without water. If all the roads to a town are blocked by fallen debris and grocery stores cannot receive shipments of food, then there is only a matter of time before food shortage becomes a life-threatening situation. If there was a proper machine that could traverse several miles of troublesome terrain, then this issue would be much more manageable. Perhaps a machine that was operated similarly to a military drone that was comprised of metals that would not rust, but was also incredibly durable. For the machine to be able to carry any kind of package, there would most likely need to be a length of five feet at a minimum. The machine would need to be able to overcome obstacles in an extremely small amount of time since a machine the size of a small human cannot carry enough supplies for more than six to eight people.

Overall, machines provide a safer and more reliable way to complete life-threatening tasks after a disaster. From delivering food to isolated towns and discovering trapped victims to replacing or repairing power lines, machines are far more efficient and secure for recovering after a natural or man-made disaster.

If further advancements to robotics are made generations to come would live a completely different lifestyle. Linemen and rescuers would no longer have to risk their lives to do their job. Robots that are controlled from afar can take over. This would prevent casualties and make repairing power lines a lot more efficient. These robots would be specifically designed to do their job. Robots could definitely change the world and force humans to adapt, but according to the current research, the benefits would outweigh the deficits. Jobs like linemen and firefighters could definitely be taken away, but new jobs will also arise. The linemen and firefighters could start learning how to control these robots as their new job. This will provide a much safer environment for the team to work in.

History

Electricity was first discovered by inventor Benjamin Franklin in 1752. Franklin did this by flying a kite during a thunderstorm. A metal key was tied to the kite to conduct the electricity. Thomas Edison, an American inventor, took this electricity and made the first successful long-lasting light bulb in 1879. Then, the issue was transferring this electricity. Edison's team wanted to move this electricity from a source to where the energy could be used. A direct current system was made, but this was very inefficient. The current caused friction which resulted in the loss of electricity. A more efficient system was needed. The first alternating current transmission system was designed by Nikola Tesla. This was much more efficient and took over direct current. In 1893, the Westinghouse Electric Company used an alternating current system to light the Chicago World's Fair. This event was a huge milestone in the world of electricity. The same year a 22 mile AC power line was made, sending electricity from Folsom Powerhouse in California to Sacramento, the longest line to date. In 1900, transmission lines reached an all-time high of sixty kilovolts. Finally, in 1957, the first nuclear power plant to provide electricity in the United States was made in Pennsylvania, called the Shippingport Reactor (The Historical Archive, 2007). Even to this day, alternating current systems are still being used for the transmission of electricity. Direct currents are only used for laptops and cellular devices. Also, nuclear power plants have proved to be a very efficient and clean source of energy. As of 2019 nuclear power is accountable for 20% of our power needs.

Current Scientific Research

Current technology allows us to create robots that are efficient with direct and alternating currents and could be controlled wirelessly. A couple decades ago, robotics might not be possible but now in this day and age, robotics is a major milestone and field in science. Competitions like BEST have promoted robotics at a highschool level offering engineering and design experience to students. Universities have also gotten involved in robotics dedicating millions of dollars on research.

Efforts have been made in China to develop a robot that can replace human jobs during the event of a power grid disaster. Dream-I is a reconfigurable live-working robot targeted towards replacing and repairing of power transmission lines. Dream-I is fully autonomous or self-operating. Dream-I is designed to accurately walk on lines without fail. The robot has two ends: an insulator replacement end and a drainage plate bolt fastening end. This allows the robot to replace and repair lines. The robot has gone through various tests of high voltage to ensure the robot will be appropriate for all situations (Yan, 2017).

Massachusetts Institute of Technology has also done intense research on robotics. MIT is trying to make a humanoid two-legged robots to replace human workers. The main issue that MIT faced was the imbalance of the robot. To solve this MIT designed a vest that could control the robot. A person could maneuver the robot by moving their own body with this vest. In theory this could solve the problem with balancing. The vest also provided feedback to the wearer. If the robot was struck by a hammer, the vest will also omit a similar action. This allowed for realistic controlling of the robot.

References

Bryan Rushing and David Elizondo (2015). Ground-Based Robots & the Future of Applications of Robots for Transmission Line. Retrieved from http://www.cce.umn.edu/documents/CPE-Conferences/MIPSYCON-PowerPoints/2015/DSIRobotsforEnergizedTransmissionLin eWork.pdf

Jeffrey Feldman (2017). How safe is that wood utility pole in your backyard?

Retrieved from https://www.electrocuted.com/2017/10/10/wood-utility-pole-safety/

N/A (2018). What does an electrical Lineman Do? Retrieved from https://www.careerigniter.com/questions/what-does-an-electrical-lineman-do/

The Historical Archive (2007). The History of Electricity-A Timeline. Retrieved from https://www.thehistoricalarchive.com/happenings/57/the-history-of-electricity-a-timeline/

Yan, Yu (2017). Development of Live-working Robot for Power Transmission Lines. Retrieved from https://iopscience.iop.org/article/10.1088/1757-899X/224/1/012027

Members and Teams

Construction	Date Applied
● Jordan Perritt	10/15/19
● Missy Gunnels	10/15/19
● Jessie Gunnels	10/15/19
● Victoria Allison	10/15/19
● Brayden Voss	10/15/19
● Jared Massey	10/15/19
● Jake Williams	10/15/19
● Jonathan Stevens	10/15/19
● Austin Plafcan	10/16/19
Notebook	
● Aaron Chen	10/16/19
● Brandon Johnson	10/16/19
● Jessie Gunnels	10/15/19
● Missy Gunnels	10/15/19
● Elizabeth Attebery	10/15/19
● Jake Williams	10/15/19

- Miranda Madden 10/15/19

Spirit

- Katie Norman 10/15/19
- Gwen Gunnels 10/16/19
- Maggie Gunnels 10/16/19
- Chloe Rowe 10/17/19

Programming

- Jake Williams 10/15/19
- Brayden Voss 10/15/19
- Victoria Allison 10/15/19

Drivers/Linemen

- Jonathan Stevens 10/15/19
- Brayden Voss 10/15/19
- Jake Williams 10/15/19
- Victoria Allison 10/15/19
- Aaron Chen 10/16/19
- Tom Norman 10/16/19

Research Paper

- Missy Gunnels 10/15/19
- Elizabeth Attebery 10/15/19
- Aaron Chen 10/16/19
- Brandon Johnson 10/16/19

Website

- Jake Williams 10/15/19
- Gentry Needham 10/18/19

Social Media

- Victoria Allison 10/15/19
- Jake Williams 10/15/19

Teachers

- Mrs. Pearson – Creator and leader of the club, Ice Breakers, provided machines and permitted materials
- Mrs. Allison – Sponsor of the club, provided machines, and permitted supplies

Sponsors:

Southern Arkansas University Engineering Department- Doctor Rashad Islam
SAU engineering workshop- Mr. Jeff Sumner (see figure 12)
Entergy Electric Company- Mr. Doug Fields (see figure 19-21)
Magnolia Fire Department- Mr. Daniel Fields
Magnolia Police Department
Albemarle- Mr. Steve Card

1. Design Process

1.1 Procedure

9-25-19

The team started brainstorming ideas on the design of the robot body. The students choose a 1 cm thick ply board for the body, to make sure that the robot was lighter.

10-2-19

The construction of high voltage towers to practice with our robot. Then, the students discussed a chassis design, two wheels with one hub. Next, the students drew a design for the front end loader model-upper and lower arm. The students determined that the original arm extension was too short for the students' needs. Lastly, the students assembled a gripper, but the servo needed to be aligned for better opening and closure.

10/3/19

Today, the students discussed possible dimensions for the chassis and decided on a tricycle design- two wheels in the back and one PVC slider in the front. The claw started malfunctioning, so the students discussed why the claw may not be working and how to fix the problem. The students thought that one issue may be that the servo attached to the claw didn't have enough range of motion due to the tip that was attached. In order to combat this, the students attached the servo with a four pronged star tip instead of the two-holed oval tip. The students decided on the new star shaped tip because the range of motion was better. Next, the students determined the dimensions for the robot's chassis. The students decided on a 16 in. length and a 9 in. width because these dimensions would house everything the robot needed. Lastly, the students began working on programming the servos that would power the robot's prototype claw.

10/4/19

Today, the students began working on the robot's chassis. A 9 in. by 16 in. piece of wood was cut out for the base of the robot's chassis. Lastly, the students discussed design ideas for a fork lift arm to push debris around the playing field. The dimensions for the fork lift arm would be 11 in. by 3 in. Lastly, the students traced out a prototype of an arm, then cut the arm out to begin conducting tests. The students identified some problems and came up with possible solutions.

10/6/19

Today, the students completed the construction involving the playing field which involved the power line connections and debris. After this was completed, the students cut out the front-loader arm and worked on cleaning up the robot's chassis. Then, the students attached the wheels and motors to the chassis. The students discussed where to mount the wheels to the chassis. The students came to the decision that the wheels should be put on the back because this location would allow more room for the hub and battery pack.

10/7/19

The hub was glued to the chassis, while other students continued with trial and error with the programming. The top arm design was ground down. The programming students discovered that the robot was set to Vex IQ as the robot brain instead of Vex Cortex 2.0. Switching to the correct program allowed students to find the correct settings.

10/9/19

Students made changes to the programming that allowed the robot to turn left. The decision was made that the smaller motors would not function as well as the larger ones due to a power deficit. Materials were also prepared for mounting the scissor lift on the prototype.Students created a model scissor lift and tested the robots motion and programming. During a programming test, a discovery was that one of the wheels was not functioning correctly due to a defective motor controller. This controller was switched out for a working one.

10/9/19

Construction on the table for the scissor lift arm prototype began. The main focus of the day was finishing the arm prototype, so the students cut out pieces and brainstormed ways to attach the gripper to the arm. The programming team began work on preparing code for the arm. Lastly, the students identified problems and tried to come up with solutions. The first problem that came up was the prototype was big in comparison to the robot. The students attempted to make a platform above the original base so more space could be utilized for the scissor lift arm. Students worked on finishing the scissor table. The students brainstormed on how and where to attach the arm to the scissor lift arm. The decision was made to mount the gripper to the arm with machine screws. A 19 in. platform was needed for scissor lift. The connector rod was too short to connect to the motor, but the students used the igus flush bearing to keep it on track and connected The students added acrylic pieces under the igus flush bearings to ensure that they were level.

10/10/19

The students attached the scissor lift arm in two places to the scissor lift table. A piece of the ply-board arm was also cut to leave a place for the servo. Ply board pieces were also cut for the servo to rest on and then the students mounted the gripper to the arm.The students were concerned about the arm staying confined within the 24 by 24 by 24 box. The students redesigned the scissor arm to stay within these limits. Wood was cut to lift the motor to the height of the igus rod. The wheels in the scissor lift table were too wide to fit in the igus slides, so the wheels were trimmed to fit within the igus slides. The students were unsure of where to position the L brackets to give the arm proper reach without exceeding the size limit, but eventually decided to mount them 4.5 in. form the front of the cardboard box. The students used PVC mounts to elevate the scissor table.

10/12/19

Students are forming the brace for the scissor lift. Card board was not strong enough to make the scissor lift out of so Students remade the scissor lift out of ¼ thick polypropylene sheets. 2400 inches squared to make the scissor lift arm. The arm is 1.5 inches by 20 inches. 36 inches of thread all were used to make a threaded connection to the motor shaft. Students are Remaking table for the scissor lift arm. The table has to be 21 ¾ in by 9 ¾ in. Students are deciding where to mount PVC pipe to support the table for the scissor arm. The support that will sit on the PVC pipe will either be cardboard or a thin sheet of plywood. The support is needed for the turntable to be able to withstand the weight of our scissor arm. The scissor arm had to be taken apart and put back together to get everything lined up appropriately. The students mounted the wheels on the scissor arm top and bottom wheels. The wheels on the scissor arm on the bottom mount to the igus sliders on the bottom which sits in the cardboard box. The wheels function to let the scissor table extend so that the claw and the arm have a greater range of reach. Two legs of the scissor table are stationary. The other two, which have wheels mounted to sit in the igus sliders, the motor makes the legs slide up and down so that the scissor table extends and contracts the arm. Students drilled holes in the chassis of the robot to mount the PVC supports. The supports are there to hold up and withstand the weight of the scissor arm.The team had to rebuild the lift table because the cardboard it was previously built with was not strong enough. Students rebuilt the lift tables so that they would overlap since the motor wouldn't flush to the igus rod. The students also mounted a PVC pipe 1 3/8 inches from the sides on the back of the robot chassis and 3 inches from the front 1 inch from the sides on the front of the robot chassis. Wood backings were added to the screws under the cardboard table to help the cardboard stay secured and hold the scissor arm in place. The students observed that the two main motors on the chassis of the robot were not sitting level with each other or the chassis. To solve this issue, the students cut two slivers of polypropylene and two slivers of PVC. One sliver of the polypropylene and one sliver of the PVC were glued together and stuck under the motors. This stabilized the motors to remain level.Students also began to create stoppers to keep the arm from falling too far forward or back on the pulley. The students made the stoppers out of wood that was cut into 3 inch by two inch pieces using the hand saw. A hole was drilled to mount the motor that powers the pulley.Students then began to drill holes in the scissor lift arm braces.A quarter inch nut was mounted into the scissor lift brackets for the thread all to run through. This should enable the lifting and lowering of the scissor lift arm. Students began to drill the quarter inch nut into the bracket.Finally, the students began to attach brackets into the scissor lift arm for alignment and stability.

10/14/19

Students moved the stopper closer to the arm to prevent it from rotating back too far. Later the PVC skid fell off the chassis so instead of using wood glue a hole was drilled as a mount for the PVC skid. The scissor lift was then secured to the bottom table. The students followed online instructions from the BEST website to set up the sensors for the autonomous functions of the robot. The students then encountered an issue where an aluminum bracket was bending instead of lifting the scissor lift. The students determined that this might have happened because the lift was too heavy. They swapped the wheel motors with the lift's motor for more power. They also added another aluminum piece to strengthen the brace. After testing the students noted that the brace was too wide, causing nuts to become loose when the lift rose. The motor succeeded in lifting the lift but the wheels on the bottom had too much drag.

Next the team set up the top (with the gripper on it) to see if the small motor would lift up the complete system. Students found is that the brace was dragging and one of the wheels is not in the track. The scissor metal arm and 2 wooden wheels were shaved down to fit in the tracks since one was not sitting in the track.

In the next test, when the scissor lift was rising with the gripper on top the metal brace bowed which made the rod pop out of the motor shaft. The students tried several solutions. One was addressing an issue where the cardboard had slack to that caused a shift in the arms. The wheels were shaved down made for a better fit on the track. The brackets were strengthened with bolts instead of glue. The students also strengthened the motor mount to prevent shifting, and moved the wheel tracks to either side.

10/15/19

When the arm moved, the center bracket caused friction by dragging the strip of wood in the bottom of the lift table. The students fixed this by turning a metal support on the bracket, which prevented it from dragging the wood. The students also used the table grinder to grind down the metal bracket so that the bracket would be even. A metal bracket connecting the motor to the scissor lift table was not flush with the bottom of the box, so an additional bolt was added to the bracket. The students also began designing cow pushers to attach to the robot to move debris. The prototype was cut out. The students then began to design a blade that will attach to the robot to move the debris into our quarter of the field during game play.Students cut out the prototype for a blade to move debris.Students began to build two more 6 x 1 inch u-brackets to support the scissor lift arm. One student conducted an interview with Doug Fields, a lineman, about the Ice Storm of 2000, as well as other robot and lineman related questions. The students tested the arm box's weight on the scissor arm lift table to determine if it was strong enough to hold. The students then mounted taller wheels onto the robot to stop the chassis from causing the bottom brace bracket between the wheels to bend.

10/16/19

The students began working on the sensors for the autonomous portion of the competition.

The students also tested the scissor lift's capabilities such as if the gripper/claw arm could be lifted. The students noticed that there was a bolt sticking out on the bottom that needed to be cut off so the scissor lift would be balanced. Students begin to mount the quartzes and the battery on the chassis. Students contemplated redesigning the arm. Students attempted to loosen the nuts and bolts on the arm the cut down the friction so that the scissor lift could handle the arm.

10/17/19

Students observed that when the scissor lift was laid down in the scissor lift table, the motor could not pick up the lift. To resolve the issue, the students decided that adding an extra motor (to lift the arm on top of the lift) under the box to prevent the lift from lying all the way down fixed the problem. A wood block was then added to prevent the arm from lowering too low. The students also designed a new arm prototype to help with the problem of the scissor lift not being strong enough. The students will mount the arm onto an L-bracket and believe that this will be able to lessen the weight being lifted by the scissor lift. The students are also loosening the nuts to reduce friction and are attempting to mount the lift onto slides. A student cut a screw in half using the dremel. The measurements of the new screw was 2 by ¼ inches. The students also began grinding another bracket to use for the scissor lift table.

The students began to cut out the new lift prototype out of wood using the bandsaw. The students also began to take their original arm design apart, so it could eventually be attached to the new prototype. Next, the students began to attach the motor and other parts to the new arm. The students designed two new boxes for the scissor lift table and the arm box and began to transfer things to the other boxes. Two holes were drilled into the scissor lift and arm brackets using the drill press. A student went to the local college to cut two extra slides for the scissor lift and the arm.The students began to mount the arm to the scissor lift table and securing all the nuts and bolts. The wheels on the scissor lift table kept getting off track so the students began to make slides for the scissor lift table to enable the use of the 1/4" rod bearing instead of wheels. The team also began to make braces for all of the scissor arms.

The students came up with a new design for the gripper arm, which will enable the elimination of the top table on the scissor lift arm. Counter-balance was needed for the opposite top brace. For counter-balance, the students weighed the new arm prototype and decided that one and a half rolls of pennies would be a sufficient counter-weight.One of the L-brackets attached to the motor was attached the wrong way so the team took the motor mount apart and reattached the

L-bracket.The students cut a counter-mount to balance the height of the second motor which was added to lift the weight of the gripper arm.Students made spacers for the ¼”Flanged Bearing, which will go in the middle of the scissor lift table to work as a guide for the threaded rod, which will be used as a shaft to pick the scissor arm up.The students used the level to determine if the threaded rod was completely level and it was determined to be straight all the way across.

10/18/19

The students mounted the arm on directly on the scissor lift as a student previously suggested. Then the students began testing the motion of the scissor lift with the arm attached.The students observed the scissor lift begin to bow and lift unevenly with the arm attached directly by a bracket.To fix the issue, the students unattached the robotic arm and discussed going back to using the arm table again. The students tested the scissor lift table to determine if it was irreparably bowed. The lift was only bowing until it reached a certain height. The students also tested the scissor lift with the DryLin Linear Bearing Carriages.One of the problems was that the scissor lift blades was found to be 1/16” wider than the other 7 blades, which caused it to lean to one side heavily. Students then secured the DryLin Linear Bearing Carriages to ensure stability.

The students will attempt to use Velcro to secure the DryLin Linear Bearing Carriages to reduce time spent fastening and disattaching if the scissor lift should have to be taken apart again. Otherwise, the students had the option to bolt the Rod End Bearings to the DryLin Linear Bearing Carriage. The scissor lift veered toward the left during a test and when raised, the Flanged Bushing came out of the connector which connects the Flanged Bushing to the motor shaft. To fix that, the students will attempt to move the DryLin Linear Bearing Carriages to the right to counteract the leftward tilt. The students began loosening screws to allow more movement in the DryLin Linear Bearing Carriages. Students glued the wheels to the DryLin Linear Bearing Carriages, and student built another bracket to have a stronger support for the scissor lift arm.

Students began securing the arm by bolting down and screwing in loose parts. The students used a level to determine that all parts are all aligned.

Meanwhile, the students began creating social media pages (Twitter, Instagram, and Facebook) to share the impact of this project on local and regional lives. In the process, students came up with a name for the team: The IceBreakers. This relates the teamrobot name to the paper in which the ice storm of 2000 was discussed.

The arm was too heavy so students used the dremel to drill holes in the wooden arm to make it lighter. The students cut the team number into the wood of the arm as a creative way to reduce the weight by using the dremel. Students later reattached the brace to the wheels The students then came up with the idea of cutting slits in the arm table to allow the top wheels to run on that as a “track”.

Scissor Lift Arm Trial Run Issues

During the first trial run, the lift worked well, but as the students started to retract it, it fell immediately. Another issue, was that when lowering the scissor lift, the shaft got caught in a bind, which led to the shaft detaching from the motor and falling immediately. The 4 supports for the scissor lifts were too low which caused the wheels not to move.To solve the issue, the students made new PVC ends that higher by adding ¾ in tee on top of the existing ¾ tees. This will allow the base to clear the wheel hubs. The students also began to cut 44 inches of 1 inch PVC to make new mounts to allow the scissor lift table to sit on the chassis. The students glued the PVC into the hole to ensure that it would stay in place.

Problems during State Competition

- Scissor lift worked but after placing gripper on top, it caused too much weight and tension
- This caused the lift to fall after only a few seconds and not reaching full height
- The tension also bent the drive shaft
- Students decided to completely abandon the scissor lift and design a pivot arm

11/9/19 Robot Workshop

During the Robot Workshop, the students finished the swivel tricycle wheel. They also made a new bracket because the holes for the axel on the other bracket weren’t centered,and drilled new holes that were bent it in two places at 90 angles. Then, the students made cotter pins out of coat hangers.The that the students mounted axel was made of the provided conduit. The students also attached the pieces with the axel, wheel, and PVC. The students then replaced the chassis of the robot with a new piece of wood that still had the dimensions 16 in/9 in. The students also put together the turntable, and made the supports for the arm out of PVC. All materials used were recorded with the axel ¾ in thick, a provided yellow wheel at 3 in, all brackets were two 2 ¼ in sections connected by 1 ½ in, the chassis at 16 in. by 9 in., and the turntable at 9 inches in diameter and ⅜ in thick.

11/11/19

The students made a cardboard box for the battery. The students also fixed the motor for the arm since the motor wasn’t lined up. Finally, the students mounted the swivel wheel, glued spacers into the arm, mounted supports for all the motors to prevent sagging, and adjusted the

PVC supports to ensure it was level.

11/12/19

Students, with the engineering department at SAU, laser cut the gripper. (See figure 32).

1.2 Problem Statement

Best robotics gave us the challenge of making a robot that is able to clean up debris after a storm and restore power to a city. The robot has to be able to increase human productivity and decrease the danger that is involved in a Lineman's job. The robot needs to be able to be placed into a 24 inch squared box at the beginning of the competition. The robot can not weigh more than 24 pounds. The robot needs to be able to remove “power lines” off of houses, rehang power lines that have been taken out in a storm, and lay underground electrical power lines. The participants will also have the option to program the robot to compete in an autonomous round. The autonomous portion will require the robot to run along the set track and deliver the supplies to the different sights around the playing field. All teams are required to build a robot out of BEST provided or approved parts.

1.3 Design Elements

There were several issues with the robot’s design. One of the major issues was constructing an arm that was capable of reaching obstacles without exceeding the dimension limits. To resolve the issue, the construction team measured the range of motion of the original arm and decided how much extra range of motion that is needed. Then, the team discussed what kind of arm would be able to increase the range of motion while still using the same servos.

2. Brainstorming and Building the Robot

2.1 Brainstorming Session

During the brainstorming sessions, students presented several ideas. (See figure 32). Some of these were used in the final designs and some were not. Ideas for strategy were also presented during these sessions. The idea for a “cow catcher” on the front of the chassis was presented in the first session. This is still included in the final design. The students had already decided to mainly focus on scoring points. The students decided not to attempt to transport skid supplies in an attempt to focus on scoring in other ways. Another idea presented was to do a closing fork-type hand to use instead of what is now the gripper. Another of the student’s less feasible ideas was to have strategic infrared sensor placement. This was rendered unusable due to a lack of skill with soldering on circuit boards. Students briefly considered using a rail slide arm instead of a straight angle arm. The students attempted to focus on autonomous delivery of supplies, but that was also unable to be used due to the misuse of circuit boards. The students also considered a one-wheeled chassis, but that idea was rejected because this would cause inefficient turns

2.2 Brainstorming Robot Chassis

The design team briefly considered reusing the previous year’s chassis. This team ultimately decided against using this due not only to the chassis’ width but also had a great deal of wear and tear from the previous competition.The construction team eventually decided on 1 cm thick plywood for the body (see figure 1). The decision was made to use a chassis design with two wheels and one PVC slider hub (see figure 3). The two wheels would be located on the backside of the robot, with a PVC slider in the front. The next time the team met, the decision was made that the body should be 16 in long and 9 in wide. This was so that the battery pack could be placed in a more discreet location, allowing for a more clean and fluid design. Another benefit to this design was that, if needed, the students could downsize the chassis to save weight for other portions of the robot. (see figure 1)

2.3 Brainstorming Arm

The students began to consider possibilities for the arm after coming up with the original design for the chassis. Two scale models were drawn of front-end loader upper and lower arms, to begin with. The students decided that a gripper should be added to this design. This idea was decided on as the original design and students cut this out at home that day. The students eventually reconsidered this design due to problems with properly utilizing a range of motion. The new arm was a simulated 10-inch human forearm with a gripper claw controlled by a servo. The arm will be controlled by a pulley system to keep in compliance with height restrictions at the start of the game.

3. Strategy

3.1 Offensive Strategy

The team's original offensive strategy was to focus on the autonomous obstacles to provide the most points. This plan failed because of sensor damage. The new offensive strategy was to focus on low hanging objects and the debris on the ground. The low hanging objects will be obtained by the scissor arm and the debris will be obtained by the “cow-pusher”.

3.2 Choosing a Strategy

The students decided to focus on more of an offensive approach rather than a defensive playstyle to conserve time. The nature of the robot’s design prohibited the students from having many defensive opportunities in general. Due to the methods the students used to design the chassis and the scissor lift, the students would not have many opportunities to prevent other teams from scoring. The driver’s only defense is to hang the second-highest wire on the public towers to prevent other teams from using those towers.

3.3 Strategies Effects on Design Elements

3.3A Offensive Design Elements

The robot was designed to act offensively. The original focus was on the autonomous round because this held such high scoring capabilities, but later in the process, the students focused more on being able to reach up to the lower hanging wires, having a claw to grab the wires, and being able to push debris into the designated point area. For the autonomous round, the students began programming and working with the circuit boards in an attempt to finish those quickly. A straight arm was also designed and mounted onto a lift table in order to be able to reach the wires for hanging on the powerlines. Another feature the students spent time on was a “cattle pusher”. The students designed an attachment to the robot chassis that was shaped like the tip of a triangle that would move debris, not only out of the way but into the scoring area.

3.3B Defensive Design Elements

The students did not focus on defense and therefore defensive strategies did not shape the design of the robot. The only defensive elements that were added to the design were the arm and the claw since the only defensive strategy involved claiming the towers.

4. Basic Design

4.1 Original Arm Design

The original design for the robot's arm was a front end loader arm model. This model would be made of plywood and would have been mounted on top of a scissor lift table that would have extended the arm enough to reach some of the lower power lines. The students focused on this specific iteration of the arm for the majority of the building time, adapting this version to different lift heights. The arm ended up being too tall, however, there was no way to lessen the height after the added height of the scissor lift and the lift table.

4.2 Arm Design Alternatives

The students briefly discussed the method of having both a rigid forearm and a pivoting upper arm model. Students came to the realization that the pivoting portion would not allow for enough upward movement to justify using this design.

4.3 Original Competition Arm

The final arm design was a rigid forearm simulated off of a human forearm. The forearm of the robot was ten inches long. The students decided that the new forearm needed to be controlled by a servo that would move up and down. This design was chosen as the final design because the robot needed a rigid forearm that was attached to the base of the chassis. At the end of this arm, a claw was placed to grab and place the wires on the hooks. The purpose of the forearm was to act as a stable base for the claw. The claw would then be able to extend and grab the power lines. The students wanted a forearm that enabled the claw to efficiently move the power lines to score points. (figure 13)

4.4 Scissor Table

The students eventually realized that a scissor table was the most logical way to solve the design problems. After discovering that the arm was too short to reach the bottom wire on the tower, the students decided to create a scissor table that would extend to enable the arm to reach the power lines. The students first modeled the table out of cardboard and realized that this material would not be strong enough (see figure 10). Polypropylene was chosen for the final version. (see figure 14) The students discovered that a balance between the table, the chassis, and the arm could be obtained by using two tables. A single table would act as a base, and the other table would act as the top table for the arm. Many problems were encountered with the scissor table. The students realized that bolts were required to relieve tension in the arm. Braces were also needed to keep the arm from bowing. If the braces were not implemented, the scissor table would have broken apart under the weight of the arm. (Refer to figure 8)

4.5 Alternate Materials for the Scissor Table

4.5A Extension arm

There were several materials that could have been used as alternatives for the robot's scissor table. The students thought about using an extension arm instead of the scissor table. The problem with the extension arm was that it exceeded the height requirement of twenty-four inches. The extension arm could not be used because the robot was already too tall, and the extension arm would increase area of the robot. Therefore, the robot would not be able to fit inside the twenty-four inch box and be able to reach the power lines. (Refer to figure 4 and 5)

4.5B IGUS slides

Originally the team was going to use the IGUS slides as the material that allowed the scissor table to lift up and down. Due to a lack of experience and time crunches to meet the team's personal goals, the team had the idea to just use the IGUS slides. The students decided to use the IGUS rods but wheels were implemented that fit in and slid along the IGUS rods.

4.5C Telescoping tubes

After the extension arm idea was discarded the students decided to focus on telescoping tubes that would slide in and out of one another. The students realized that the only material used to construct the telescoping tubes was the ¾ inch PVC pipe and a one inch PVC pipe. This would allow the telescoping tubes to not slide in and out of one another. However, the students discarded this idea because of the insufficient amount of materials

4.6 Final Scissor Table

The final design for the scissor table was a variation of the IGUS slides. A motor was attached at the opposite side of the scissor table and attached to a thread-all rod, which was mounted onto the end bearings. A motor, with a string attached. was connected to the cardboard base under the scissor arm. A second cardboard base with the arm attached was mounted at the top of the scissor arm at the same side as the first base. The string from the second motor traveled up to the claw. The scissor lift was attached to the robot and wired. (Refer to figure 2)

5. Claw

5.1 Claw Design

The original claw design was to use two separate gripper pieces attached to gears that are hooked up to the servo. The gears attached to the separate claw pieces are against each other so that when one gear turns and moves the piece, the opposite gear does the same. (see figure 6)

5.2 Claw Alternatives

In the alternative design, the gears were replaced with long, thin rectangle pieces that were hooked up on a star-shaped piece on the servo. The rectangle pieces are attached to each other on a pivot so that the two pieces are pulled shut when the star piece turns and pulls the rectangles back. When the servo turns the other way, the claw pieces are pushed outward.

5.3 Claw's Final Design

The alternative claw design was used in place of the original. The gears were going to be too difficult to make, and the gears were not already provided. The gears were too small for the team's equipment. Also, the rectangle pieces were found to make sufficient use of the incredibly limited turning radius of the servo. The students decided to use one of the 3-D printed pieces instead of focusing on creating a final claw.

6. Programming

Programming was an essential part of the construction of the robot. Without programming, the robot would not have been able to operate. The first decision the students had to make was what programming language to use. The students chose RobotC because the program is a dependable language that was more widely used than the other options such as using Simulink or Python. Wide use meant that if problems were encountered, the students could solve the issue by referring to previous cases where others had the same problem. There was more documentation of how the program worked. In addition, C, the language that RobotC is based on, is a popular, widely used programming language as well. Since RobotC is based on this language, the students had a chance to become familiar with the syntax of a popular and important language. When the students started programming, the team considered how the robot should move and what buttons/joysticks would control those movements. The students decided on a 2 joystick movement system in which the left joystick controls forward movement, while the right controls leftward and rightward movement. The other motors and servos (arm, claw, scissor lift) are controlled by buttons and triggers. A code snippet has been marked up to explain the process and the variables. (see figure 7.)

7. Drivers

The students waited until the robot was almost done to decide the drivers. Each individual would test drive the robot in a mock competition. This was to determine which individuals would be able to achieve the most points within a certain time limit. The results of this test were recorded and made into two data tables to determine the drivers. See figure 22.

8. Robot Testing

During the first testing, the scissor lift was rising with the gripper on top the metal brace bowed which made the tread pop out the motor shaft, and the robot worked with the small motor. Complications arose when students added the gripper base to the scissor lift. (see figure 11) With the robot's gripper attached the scissor table was weighed down and dragged on the wooden plank in the base.The students discovered that if the metal support on the bracket was turned, the bracket no longer dragged. A table grinder was used to even up the metal bracket.

The table weight was tested on the scissor arm lift. The table caused the drive shaft brace to bend. The team determined that taller wheels on the arm might prevent the bracket from bending. The students also tested the scissor lift's capabilities to lift the gripper/claw arm. The arm was too heavy for the scissor table to lift. Students attempted to loosen the nuts and bolts to cut down on the friction so that the scissor lift could handle the arm. When the scissor lift was laid down in the scissor lift table, the motor could not lift the table. Moving the motor to the base would help support the scissor arm and relieve some of the tension and excess weight on the table. The team determined that another support at the same height as the motor would be needed on the other side of the scissor lift. The next problem was that the wheels on the scissor lift table kept getting off track. Students made slides from the IGUS linear guides for the wheels. Students used flanged bearings to help guide the threaded rod. Students observed that the scissor lift began to bow and lift unevenly with the arm attached directly by a bracket. The students discussed how to fix the bowing problem, and tested the scissor lift with the DryLin Linear Bearing Carriages. One of the scissor lift blades was found to be wider than the others, causing the lift to lean to one side. Students stabilized the lift. The arm was found to be too heavy, so the students made holes in the arm to lighten the arm. The threaded rod began to become unattached if the lift was lifted too high, students decided that the lift should not be lifted past a certain point.

9. Team Meetings and Organization

A team meeting was held on the 23rd of September to discuss the robot. Students were assigned to one to three teams based on skill. All students were informed about the requirements of the notebook, research paper, programming, and construction of the robot. For the notebook, the team created a document on Google Docs so that everyone could all work on the document at the same time without the need for copying and pasting. Students were informed about the task at hand, including the requirements, at least a week before their tasks were due. All drawings of the robot's design were kept in the sponsor's classroom. See figure 23.

10. Safety

Students strived to fulfill all appropriate safety regulations throughout the six week building period. The students even invited a local small business owner, Rob Gunnels, from Gunnels Mill Incorporated, to teach safe and proper usage of machinery on September 27, 2019. Mr. Gunnels demonstrated how to use all relevant equipment and explained exactly what safety procedures needed to be followed. Following that meeting, the students had a much better working knowledge of this equipment and how to safely and properly go forward with the construction.

11. Problems at Competition

11.1 Problems With The Arm: The students loosened the pulley string excessively and the string became unspooled and was unable to lift the back end of the robot up. In addition to these mechanical failures, the arm also broke when one of the students bumped it against a wall.

11.2 Cowcatchers: The cowcatchers were not fastened well with epoxy and when the robot hit an arena wall, the cowcatchers came loose and eventually fell off. The students were forced to use electrical tape and duct tape for reattachment. Occasionally the cowcatchers did not stop the debris from getting caught under the robot and the robot became high-centered on the debris.

11.3 Problems with Scissor Lift: Students were concerned with using the scissor lift due to the unpredictability of the part. The thread-all would occasionally pop of the connector and this caused the scissor lift to collapse. However, this never consistently occurred and students were unable to determine its cause.

11.4 Problems with the Wheels: Students believe that the wheels could have had a traction problem. If the wheels were having traction problems this was because the wheels were not always touching the ground. The students also thought the problems with the wheels could be due to low hanging wires.

11.5 Problems with Wires: Students had problems with getting wires to stay in place because the wires continually popped out of place and this caused things to not work.

12. Force on Pivot Arm

The force on the pivot arm was located on 98 cm from the end. The load was located at 1.0 cm and weighed 250g. Force is directly proportional to distance from load. Force decreases as distance from load decreases. Students decided to increase effort arm distance to decrease force required to pick up load (250g). Force table on figure 24.

$F_1d_1=F_2d_2$ Increase of effort end to decrease force on meter length.

load=effort.

Appendix

Materials Used - Quantity

Cortex Microcontroller [1]	Futaba Servo [1]	1/2” plywood 12”x24”
Vexnet Joystick [1]	Servo horn screw [2]	¾” PVC pipe, -14”
Vexnet Key 2.0 [2]	Servo horn [1]	¾” PVC 90 elbow [2]
Motor Controller 7.2V 4A [4]	#8-32 x 1- ¼” nuts, steel [20]	¾” PVC tee (slip) [6]
Large Motor [2]	40” servo cable [2]	L bracket [2]
Small Motor [2]	24 tooth drive pulley [1]	Hinges [2]
Motor controllers [4]	BEST IR Sensor Kit [1]	All-purpose duct tape, 2”
7.2 V NiMH battery [2]	Roller blade wheel [1]	Painter’s tape,
Charger Adapter [1]	Igus Glide [1]	Carpenter’s wood glue
Screw Terminal Sensor	Igus Flanged Bearing [1]	epoxy
Interface Cable 3-wire [4]	⅛” PVC sheet 12”x12”	#10-32 x 1- ½” screws
Servo Power Adapter	Al flat 4”x4”	#10-32 machine screw nuts, 1
Battery Charger [1]	Al sheet 12” x 12”	#10 flat washer, steel
Rechargeable Batteries [1]	Al rod [1]	#8 machine screws [20]
#8 washer [28]	Micro switches [4]	24” servo cable [2]
#2-56 x 1” screws [6]	Velcro strip 4”	Clothes hanger wire 8”
#2 flat washer, steel - 6	Seine twine [4]	Team Custom Part 3 (gripper)
#6 x 1” wood screws -12	VEX motor mounts [4]	½” metal conduit - 3”
Pully (large) [1]	Cardboard ¼” 8” x 8”	Clothes hanger wire 8”
½” metal conduit - 3”		

Figure 1

Early chassis sketch

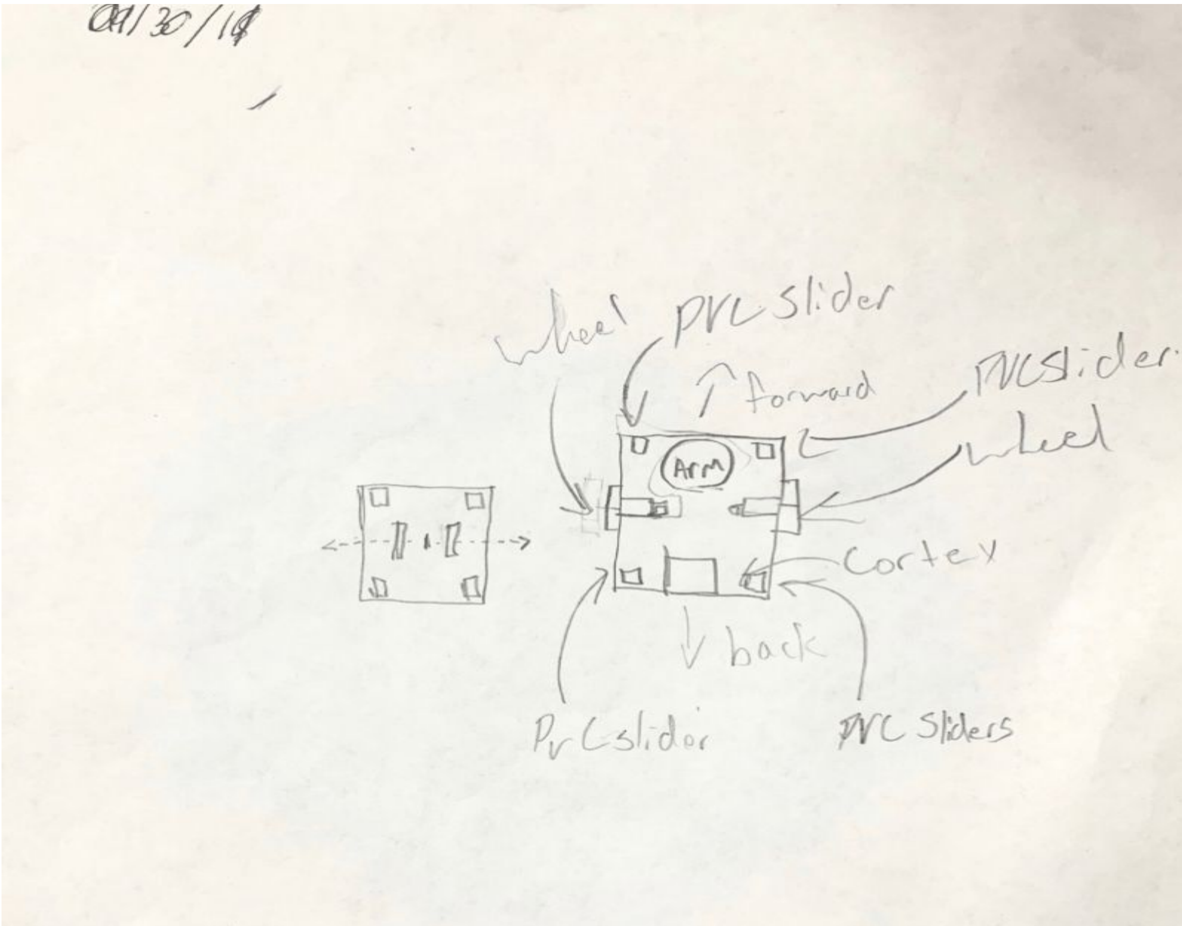


Figure 2

Final scissor table design

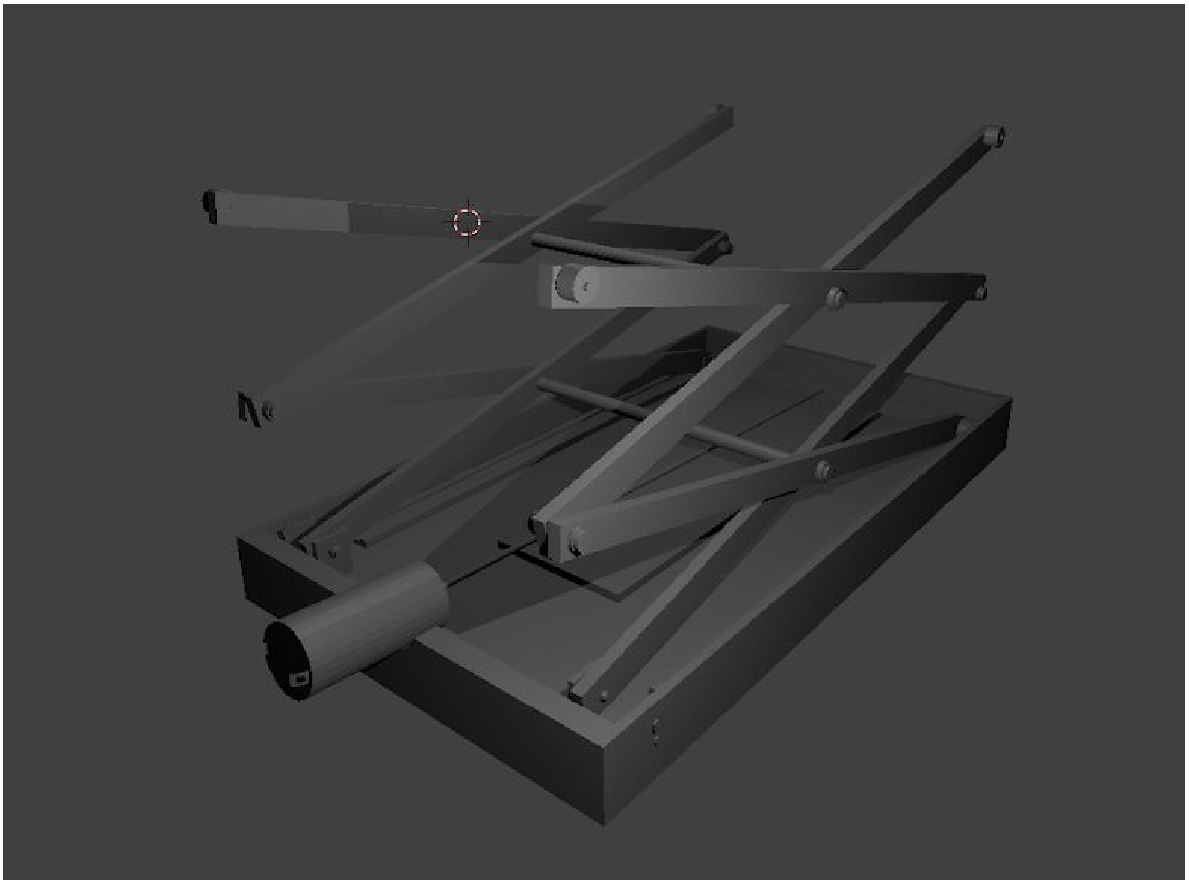


Figure 3
The final robot chassis design

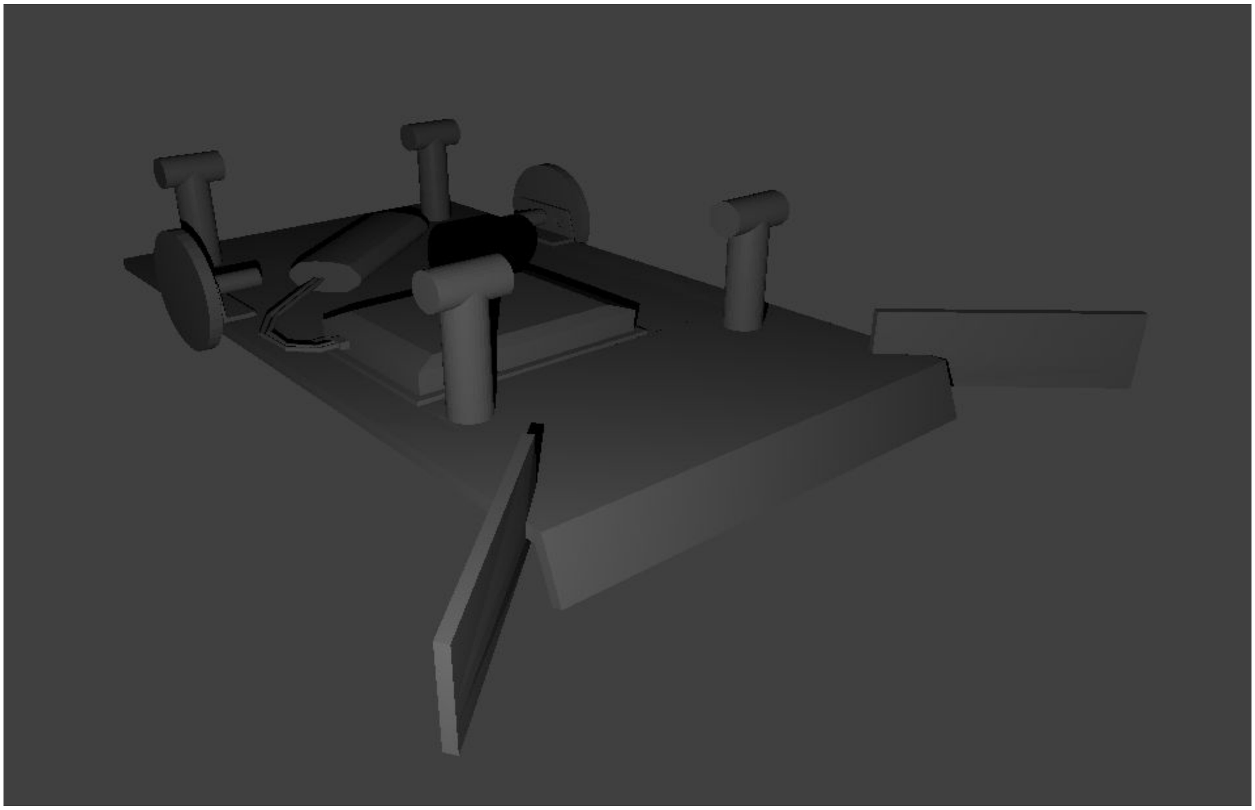


Figure 4
Scissor table and rack and pinion

Figure 5

Extended scissor table

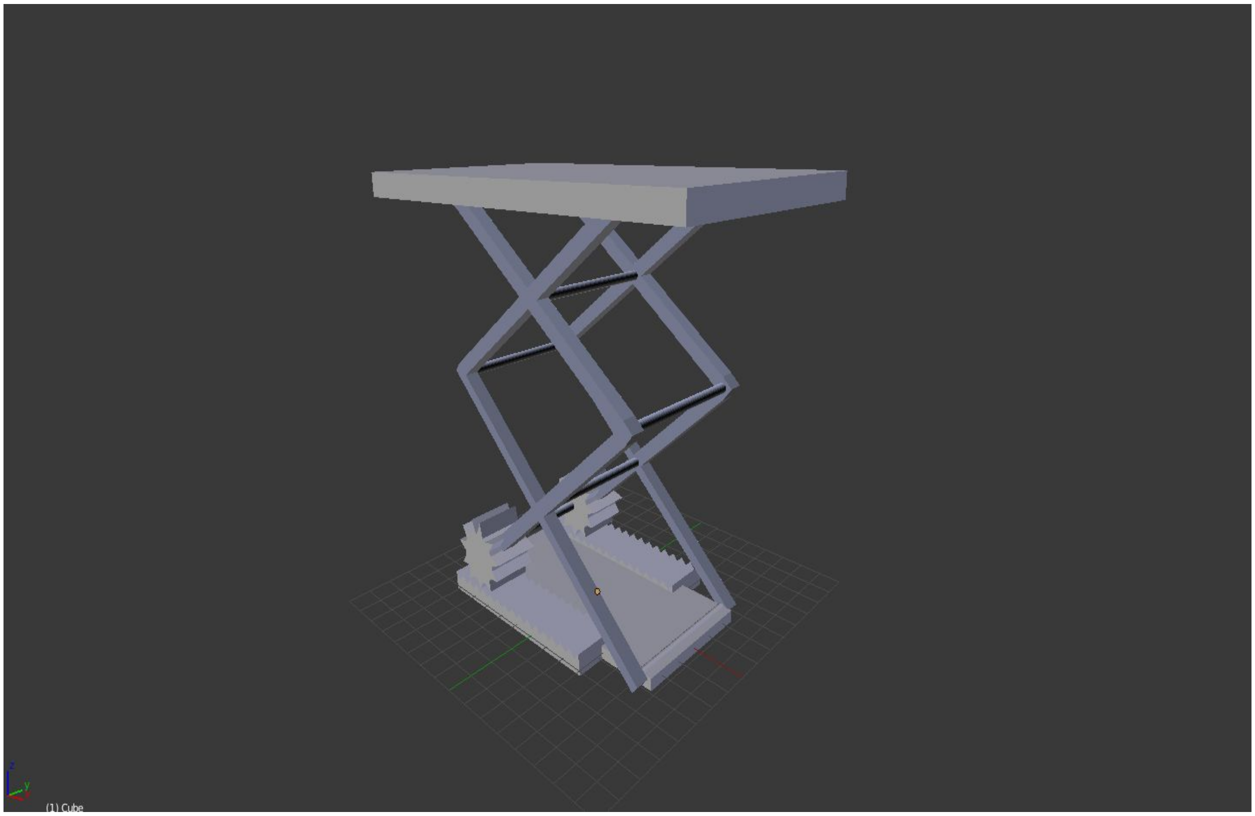


Figure 6

Initial drawing of the arm with gripper design

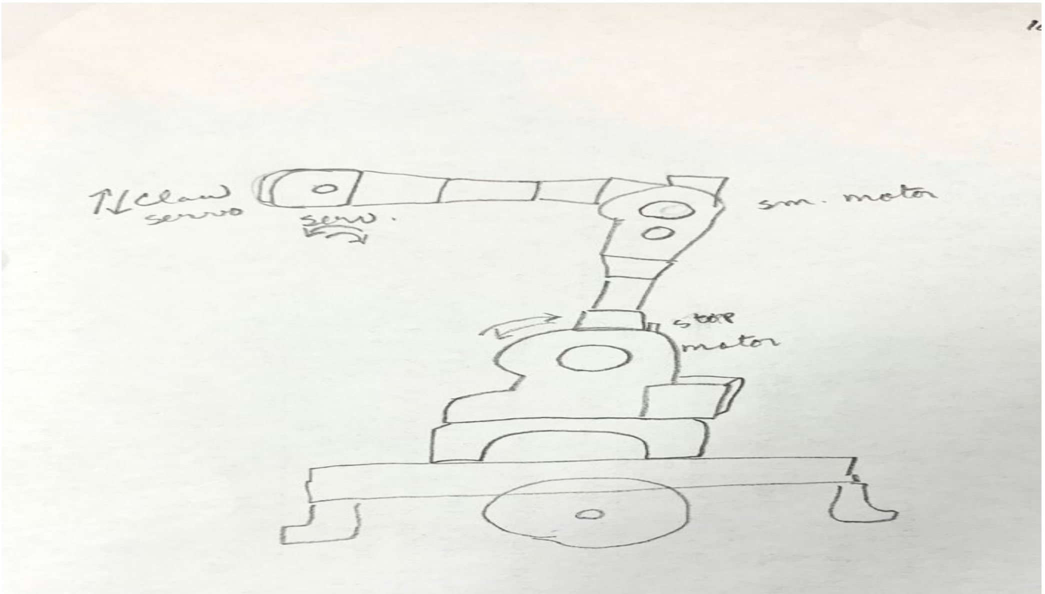


Figure 7

This is the 5th full revision of the program that controls the robot

```
#pragma config(Motor,  port2,           leftWheel,     tmotorVex269_MC29, openLoop)
#pragma config(Motor,  port4,           rightWheel,    tmotorVex269_MC29, openLoop)
#pragma config(Motor,  port6,           scissorLift,   tmotorVex269_MC29, openLoop)
#pragma config(Motor,  port7,           arm,           tmotorVex269_MC29, openLoop)
#pragma config(Motor,  port9,           claw_servo,    tmotorServoStandard, openLoop)
//*!!Code automatically generated by 'ROBOTC' configuration wizard  !!*//
//The above is autogenerated by the 'Motor and Sensor Setup' menu.

#define sensitivity 0.0001 //Increase this value to make the claw move slower, but be more fine controls. This value
stays constant throughout the operation of the program

task main()
{
	/*
	Initialization of variables
	---------------------------
	claw - controls and stores the degree at which the claw servo is turned. Value can be between -120 and 120
	modifier - This stores a value between -50 and 50.  -50 is the sharpest left, 50 is the sharpest right.
		This value is set and determined further on in the program.
	lSpeed - This is the speed of the left wheel motor.  The value is stored between -127 and 127.  The students
use
		Two different speeds to perform turns
	rSpeed - This is the speed of the right wheel motor, which stores a value between -127 and 127.
	*/
```

```
	int claw = -120;
	int modifier = 0;
	int lSpeed = 0;
	int rSpeed = 0;

	//Infinite while loop evaluates to true forever to keep the robot running until the loop is interrupted.
	while(true)
	{
		if(vexRT[Btn5U] && claw < 120) //If the 5UP button is being pressed(evaluates to true) and the
claw degree value is less than 120, then the value of the claw decreases by 5
		{
			claw += 5;
			wait(sensitivity); //This wait prevents the claw from opening too fast so the driver can
have more refined
						//control of the claw
		}
		else if(vexRT[Btn5D] && claw > -120) //If the 5DOWN button is being pressed(evaluates to true)
and the claw degree value is more than -120, then the value of the claw will decrease by five
		{
			claw -= 5;
			wait(sensitivity); //This wait prevents the claw from closing too fast so the driver can have
more refined control of the claw
		}
		motor[claw_servo] = claw; //Sets the claws servo position to the value stored in the claw variable
that has been manipulated in the preceding statements

		if(vexRT[Btn6U]) //Turns the arm in a clockwise direction if the 6UP button is pressed(evaluates
to true)
		{
				motor[arm] = 127;
		}
		else if(vexRT[Btn6D]) //Turns the arm in a counterclockwise direction if the 6DOWN Button is
pressed(evaluates to true)
		{
				motor[arm] = -127;
		} else { //If nothing is being done, the arm motor will be turned off
				motor[arm] = 0;
		}

		if(vexRT[Btn8U]) //If the 8UP button is pressed(evaluates to true), the scissor lift will be lifted by
spinning the motor in the clockwise direction
		{
			motor[scissorLift] = 127;
		}
		else if(vexRT[Btn8D]) //If the 8DOWN button is pressed(evaluates to true) the scissor lift will be
released by spinning the motor in the counterclockwise direction
		{
			motor[scissorLift] = -127;
		}
		else //If neither of the 8DIRECTION buttons are being pressed the motor is turned off
		{
			motor[scissorLift] = 0;
		}
```

```
			/*The modifier is set to the value of the Ch1 joystick direction.  The division by 2 makes the value max out at -50 and 50
			 So that when the value is added to the forward direction, 100 will not be exceeded;
			 The reason for this added is so that the robot can turn while still making progress in a forward direction*/
			modifier = vexRT[Ch1] / 2;

			if (modifier < 0 && vexRT[Ch3] == 0) //If the 3rd joystick axis is not doing anything and the other one is to the left, the robot turns left with no forward movement at a faster turning speed
			{
				lSpeed = -100;
				rSpeed = 100;
			}
			else if (modifier > 0 && vexRT[Ch3] == 0) //If the 3rd joystick axis is not doing anything and the other one is to the right, the robot turns right with no forward movement at a faster turning speed
			{
				lSpeed = 100;
				rSpeed = -100;
			}
			//If the right joystick is turned to the left( < 0 ) and the left joystick is forward ( > 0 ), the robot uses the following formulas to determine speed
			//The formulas were chosen as a way to continue forward progress while still retaining the ability to turn
			//the left wheel is the value of the left joysticks forward value divided by 2.  The other is the same, except the modifier is subtracted(a negative value, which causes addition)
			//The same principle applies to the other formulas. The students are just slightly modified for different directional movement
			else if(modifier < 0 && vexRT[Ch3] > 0)
			{
				//Left Turn
				lSpeed = vexRT[Ch3] / 2;
				rSpeed = (vexRT[Ch3] / 2) - modifier;
			}
			else if (modifier > 0 && vexRT[Ch3] > 0)
			{
				//Right Turn
				lSpeed = (vexRT[Ch3] / 2) + modifier;
				rSpeed = vexRT[Ch3] / 2;
			}
			else if(modifier < 0 && vexRT[Ch3] < 0)
			{
				//Back Left Turn
				lSpeed = vexRT[Ch3] / 2;
				rSpeed = (vexRT[Ch3] / 2) + modifier;
			}				else if (modifier > 0 && vexRT[Ch3] < 0)
			{
				//Back right turn
				lSpeed = (vexRT[Ch3] / 2) - modifier;
				rSpeed = vexRT[Ch3] / 2;
			}
			else
			{
```

```
				//Straight
				//if the only joystick in movement is the left one, then the only movement is forward or
backward tspeed
				lSpeed = vexRT[Ch3];
				rSpeed = vexRT[Ch3];
			}
			//Sets the motors to the values that were set in the preceding statements
			setMotor(rightWheel, rSpeed);
			setMotor(leftWheel, lSpeed);
		}
}
```

Figure 8

Mrs. Pearson and Missy Gunnels working on scissor table

Figure 9

Jonathan Stevens working on rack and pinion

Figure 10

Miranda Madden cutting cardboard for original scissor lift

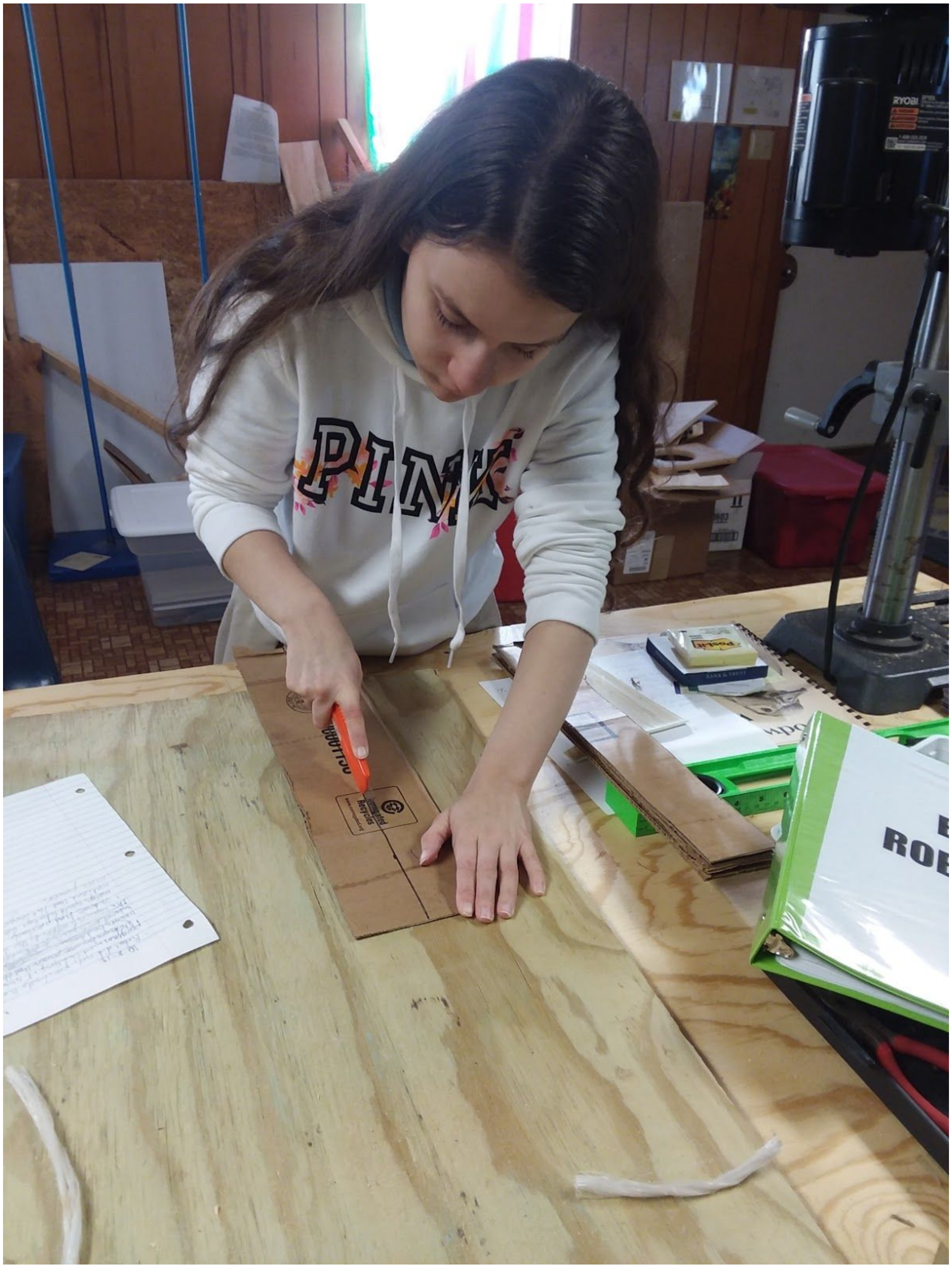


Figure 11

Jordan Perritt working on aligning the drive shaft on the scissor table.

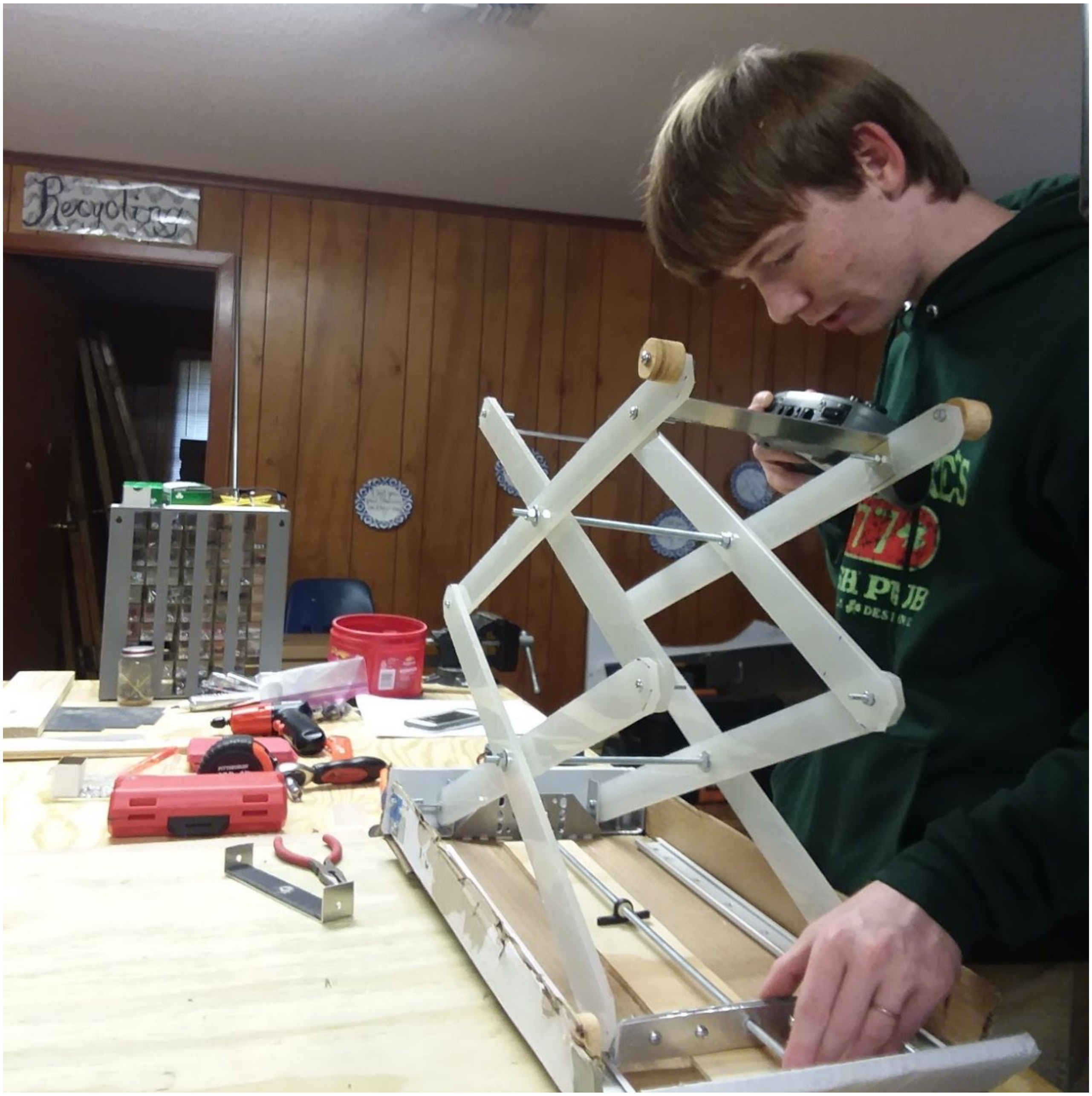


Figure 12

Jonathan Stevens cutting metal for arm

Figure 13

Jake Williams working on the robot arm

Figure 14

Victoria Allison working on the scissor table

Figure 15

Miranda Madden logging daily notes for the notebook team

.

Figure 16

Jordan Perritt and Jonathan Stevens discussing arm designs

Figure 17

Jonathan Stevens at the SAU engineering workshop

Figure 18

Brandon Johnson using a bandsaw to form pieces of the arm

Figure 19

Missy interviewing Doug Fields

Figure 20

Doug Fields from Entergy standing in front of his truck

Figure 21

Missy Gunnels and Doug Fields after the interview

Figure 22

Robot practice runs

Name Trial 1	Time (min)	Debris	PVC cable	Low Power Line	High Power Line #1	High Power Line #2	Power Line Homes	Points
Jake	3 min	2	0	2	1	0	0	190
Jordan	3 min	3	0	2	0	0	0	260
Jared	3 min	1	1	1	0	0	1	130
Brayden	3 min	2	1	2	1	0	1	300
Ryan	3 min	1	0	2	1	1	0	320
Jessie	3 min	1	0	1	1	0	1	210
Victoria	3 min	3	0	1	1	1	1	350
Missy	3 min	1	1	0	1	0	1	180
Elizabeth	3 min	3	0	1	0	0	1	150

Figure 23

Dates of team meetings

September

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25 First Team Meeting: 1:45 - 2:38pm	26	27 Meeting: 1:45 - 2:38pm	28
29	30					

October

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
		1	2 Meeting: 9:40 - 11am	3	4	5 Meeting 9:30 - 12:30 pm
6 Meeting: 2-4:30pm	7	8	9 Meeting: 9:40 - 11:25am	10	11	12
13	14	15	16 Meeting: 12:52 - 1:45pm	17	18	19 Practice Day
20 Meeting 2-3:30pm	21	22	23 Meeting: 9:40 - 11:25am	24	25	26
27	28	29	30 Meeting: 1:45 - 2:38pm	31		

Figure 24

Force of Pivot Arm Table

Fulcrum location (cm)	Effort Force (N)
30 cm	50 N
40 cm	150 N
50 cm	220 N
60 cm	400 N
70 cm	640 N
80 cm	1200N

Figure 25

Pivot Arm Robot Design

Figure 26

Pivot Arm Design (Back)

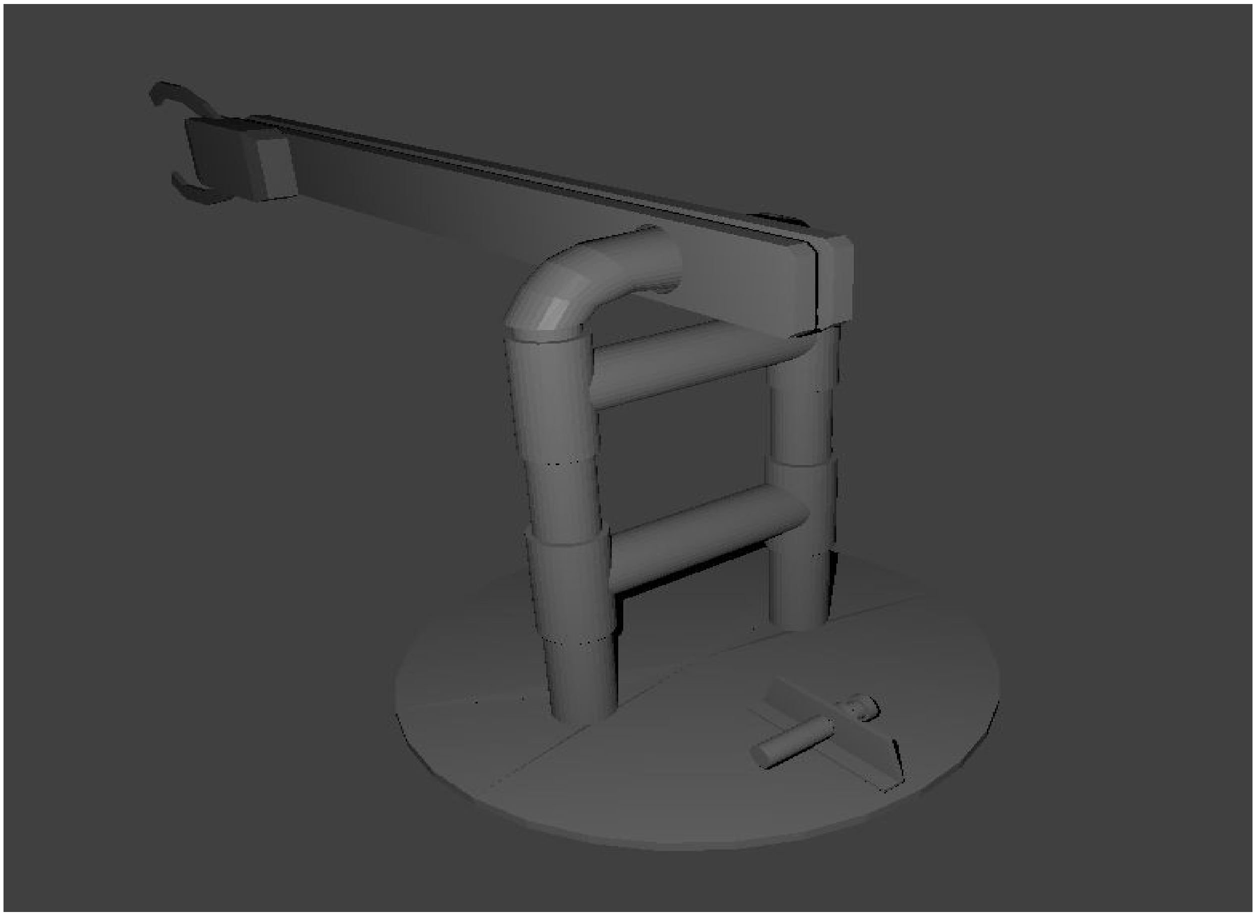


Figure 27

Pivot Arm Design (Front)

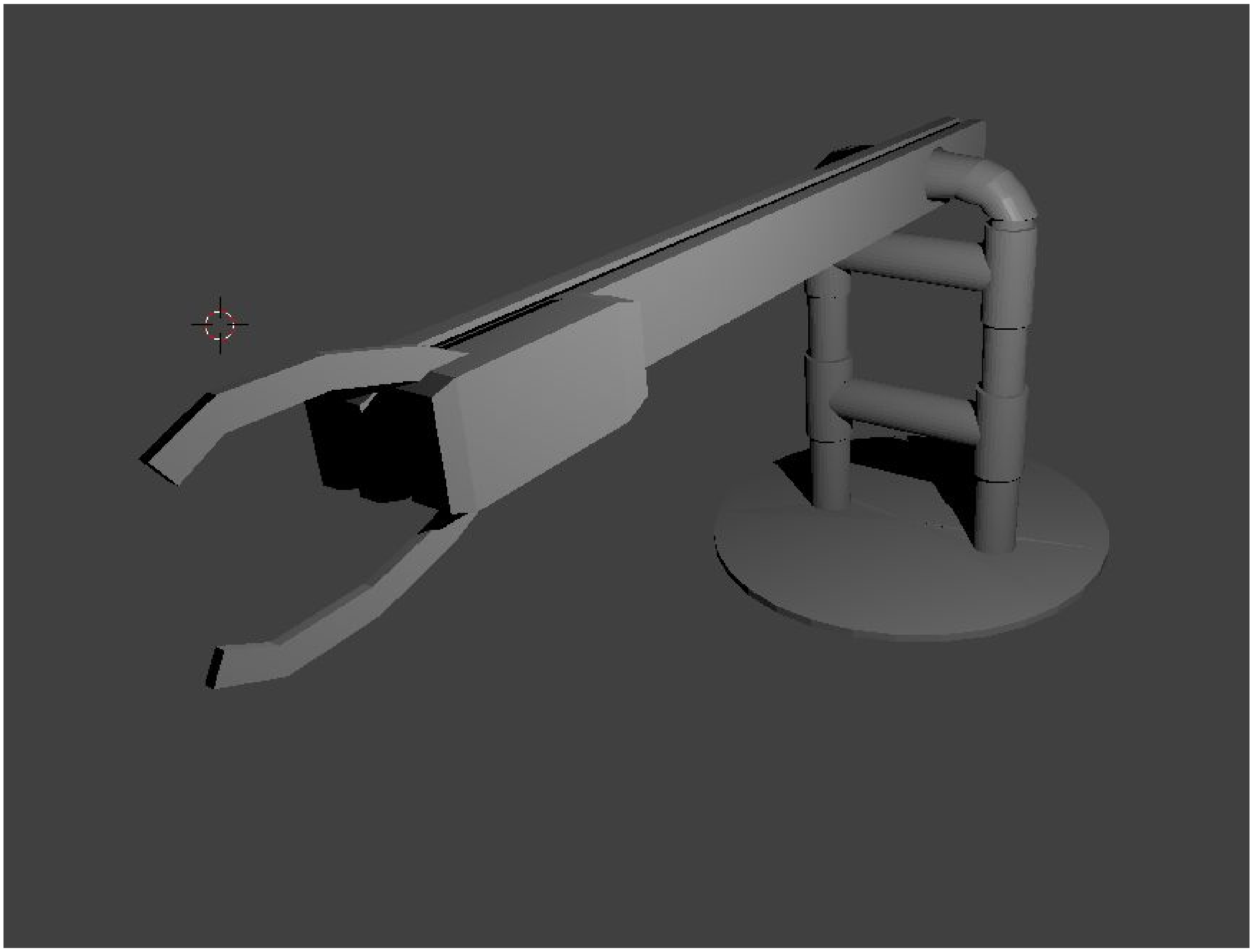


Figure 28

Jonathan Stevens and Brayden Voss working on new pivot arm design

Figure 29

Pivot Arm Design

Figure 30

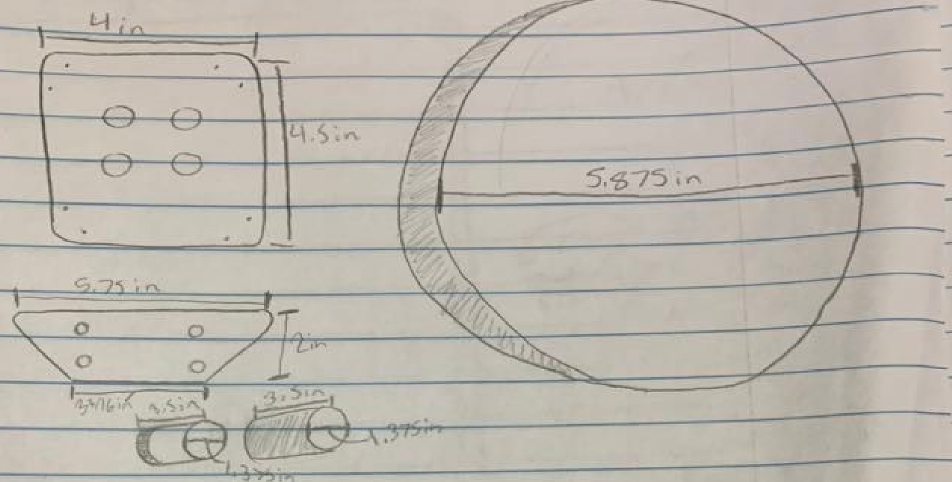
Jordan Perritt drilling new robot together

Figure 31

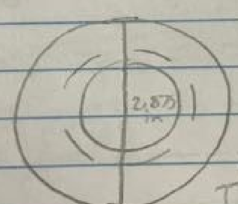
Pivot arm robot design dimensions

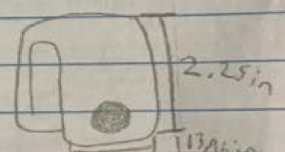
11-11-14

Back Wheels

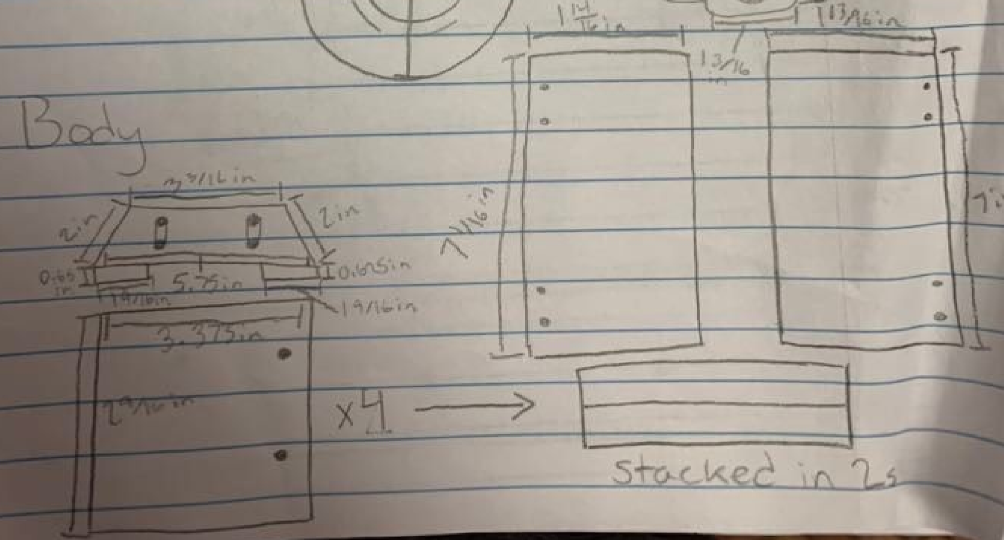


Front Wheel



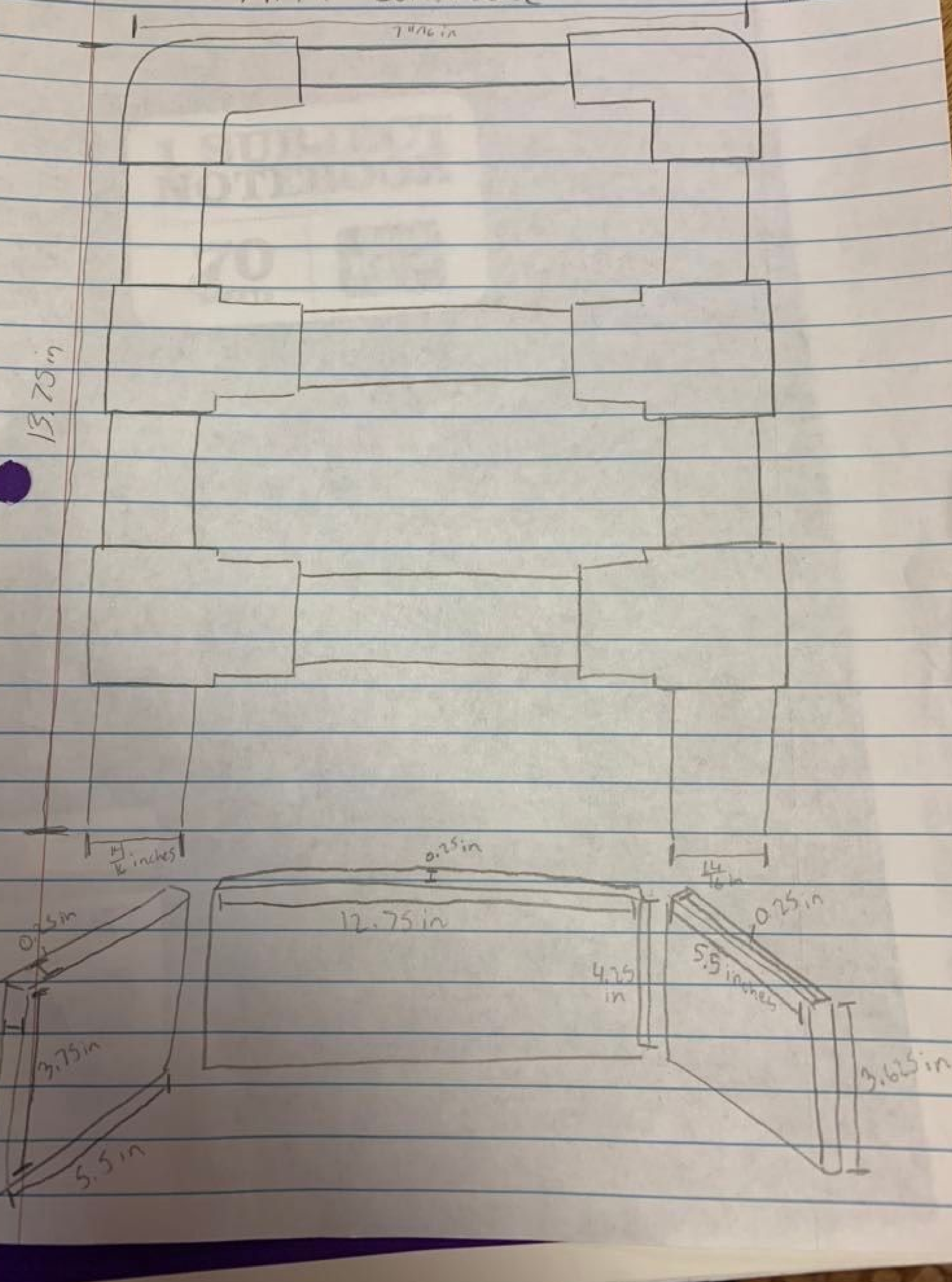


Body



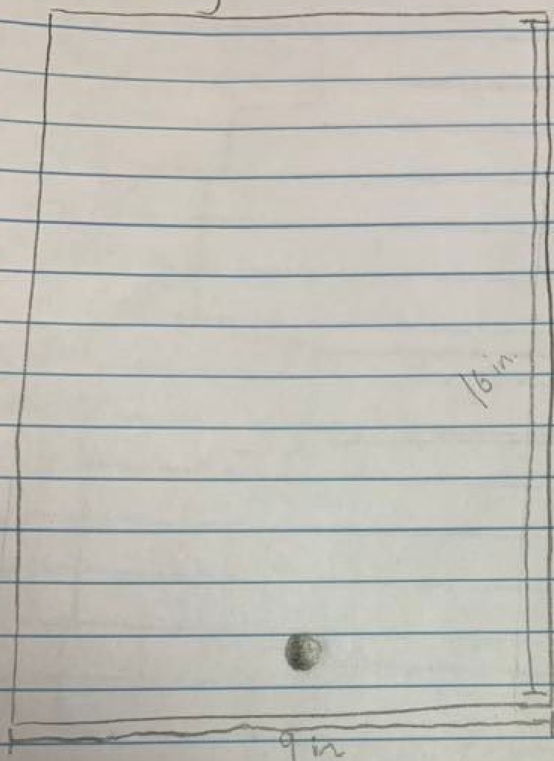
Arm continued

11-11-19

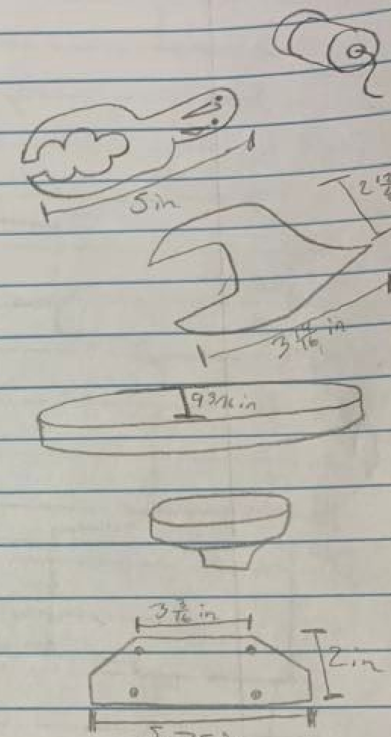


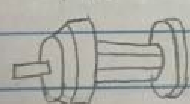
Body continued

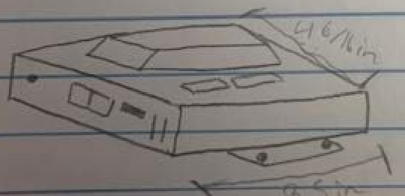
11-11-19



Arm







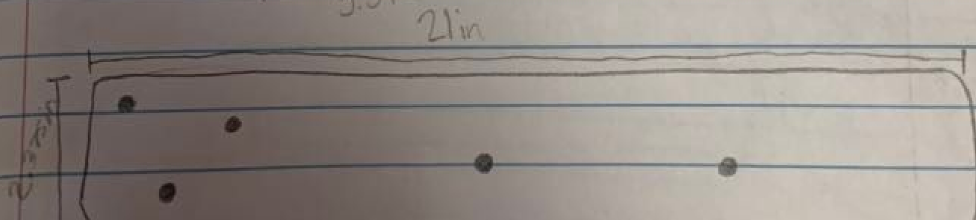


Figure 32

Laser cut gripper specifications

Height	Layer Height	Maximum Shells Overlap Percentage	Infill Density	Shells	Estimated Print Time	Estimated Amount
0.25mm	0.30mm	50%	20%	2.0	5 min, 48 sec	0.9g/0.29m

Figure 33

Jake Williams, Jonathan Stevens, and Brayden Voss thinking about new design

Figure 34

Aaron and Ryan cutting out the first chassis