ARCHER Robotics

Anoka Region Christian Homeschool Engineering with Robotics

2012 Engineering Notebook

Team Number - B9643

Coach - Eric Lofstad

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1. INTRODUCTION

ARCHER Robotics is an industry leader in design and construction of advanced robots to transport supplies and ultimately life into space. We have extensive engineering experience in the field of robotics, both on earth and beyond. Our employees have been involved in the design process of the International Space Station, the *Curiosity* rover, and Robonaut II. At ARCHER Robotics, both of our design and manufacturing staff are dedicated to a project from beginning to end. Our design engineers monitor every step of the building process to ensure complete, quality products.

ARCHER Robotics has answered BEST Robotics, Inc.'s call for a fully functional robot to assist in construction of Midway Station, the first stop on a journey to the top of the space elevator. In order to accomplish this goal, the robot must transport cargo to and from the station, deploy solar panels to power the station, and install a habitation module so that people can live at the station. The robot must also be able to bring waste back to earth and test a new T-structure device that could possibly be used to mount new additions to the station. In order to design and build such a robot, ARCHER Robotics has gathered together a group of leading engineers and technicians to form Team ARCHER. The hope of ARCHER Robotics and BEST Robotics is to build a space elevator within this decade, a goal that is within mankind's reach.

2. Team ARCHER

Engineering Team


Jacob 6th grade


Parker 9th grade


Naomi 6th grade

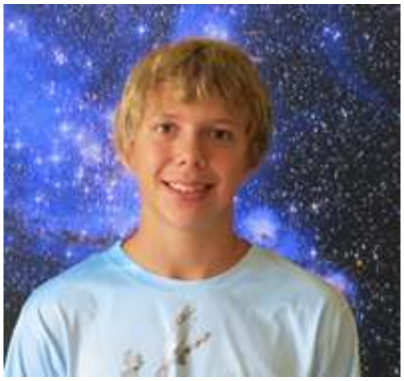
Marketing Team


Vivi 8th grade


Cameron 6th grade


Daniel 6th grade


Calhoun 6th grade


Mason 8th grade

BEST Team Demographics - 2012

Submission of this completed form is ***required*** as part of the **Project Engineering Notebook** submitted at the local hub competition. We request that it **be completed just prior to submission of the notebook for judging.**

School Name: ARCHER **City/State:** Anoka, MN

Most correctly describes school location: ☐ Rural ☐ Urban/City X Sub-urban

Type of school (check the box): ☐ Public ☐ Private X Home school ☐ Other:

Type of school (check the box):
X Middle/Jr. High X High School ☐ K-12 ☐ Other:

Which most appropriately describes the total student population at your school:
X 1 to 399 ☐ 400 to 799 ☐ 800 to 1199 ☐ 1200 to 2000 ☐ greater than 2000

Number of students on BEST team by grade:
K - 5th: **6th:** 5 **7th:** **8th:** 2 **9th:** 1 **10th:** **11th:** **12th:**

Number of students on BEST team by race (<u>optional</u>):
African-American: **Asian American:** **Hispanic:** **Native American:**
White: **Other:**

Total number of students on BEST team:
Number of males: 6 **Number of females:** 2

Total number of students who worked on the robot: 8
Total male: 6 **Total female:** 2

Total number of students who worked on the BEST Award: 8
Total male: 6 **Total female:** 2

Approximate number of students on your BEST team likely to pursue careers in engineering, science, math, or technology: 2 **Total # of male:** 2 **Total # of female:**

Total number of adult mentors assisting your BEST team (NOT including teachers): 2

This year, is BEST being integrated into any STEM (Science, Technology, Engineering, Math) curricula at your school? X YES ☐ NO

As a direct result of participation in BEST, has your school adopted/developed an engineering course(s) or curriculum? ☐ YES ☐ NO X N/A (our school does not offer engineering courses/curr.)

Of the software provided by BEST Robotics, our team/school used the following (check all that apply):
X SolidWorks ☐ MathWorks Simulink X easyCv4 ☐ RobotC
☐ Mathematica ☐ HSM Works ☐ InspirTech (SolidWorks Training)

3. REASEARCH PAPER

A space elevator is a type of space transportation involving machines that travel up and down a ribbon-like cable that reaches far into space. It costs less than a rocket as is doesn’t use expensive rocket fuel. The cost to transport items into space via space shuttle is over $10,000 per pound. An elevator could do it in less than $100 per pound.

The construction process begins with bringing a large spool of the cable into space on board a satellite. When at the correct location and altitude, the spool unwinds more than 22,236 mi (35,785 km) down to an awaiting ocean-going base. The end of the cable is then attached to the base. Meanwhile, a counterweight is attached to the space-ward end of the cable, keeping the cable taut, stopping it from falling to earth. The space elevator is also called a beanstalk, space bridge, space lift, space ladder, skyhook, orbital tower, and orbital elevator.

3.1 History and Development of the Space Elevator

The idea of a space elevator first came from a Russian scientist named Konstantin Tisolkovsky in 1895. While on a trip to Paris, he saw the then recently constructed Eiffel Tower, and imagined connecting a long tether to the top of the tower that reached into space and connected to a “Celestial Castle” that orbited the Earth. He calculated the altitude that an elevator would have to reach in order to stay above the same point on earth. This height is called geosynchronous altitude, and on earth is 22,236 mi (35,785 km) above sea level. With this large number he declared a space elevator impossible, and the idea was forgotten for more than sixty years.

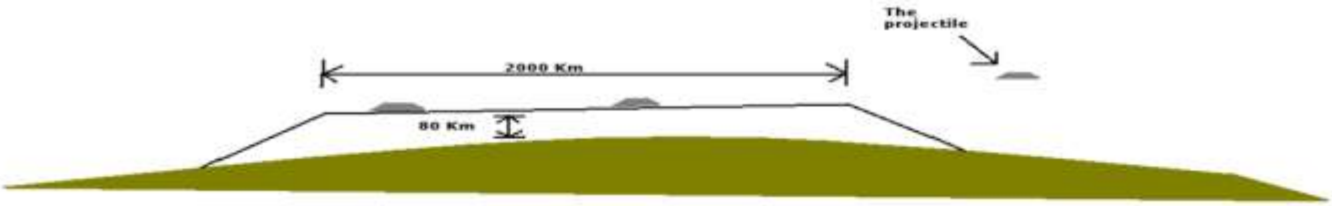
During the 1960's, various scientists examined the idea, but found problems and declared the elevator impractical. In 1975, Jerome Pearson published a technical paper on the elevator, and the idea was finally considered as within the realm of possibility. Pearson's papers were the inspiration for Arthur C. Clarke's novel *Fountains of Paradise,* in which engineers build an elevator on top of a mountain on the fictional island of Taprobane. This marked the first time the idea of a space elevator was brought before the public. However, there still wasn't a material both strong enough and light enough to use for the cable. The material for the tether would have maximum stress at geosynchronous orbit. The stress would decrease exponentially as you neared Earth. The tether would need to be a certain size at geosynchronous orbit, but taper down as altitude decreased. The stronger the material, the less it would have to taper. Steel is too weak to use, and diamond, although strong enough, is very brittle a cracks easily. It seemed nothing would work to use as a cable. This all changed with carbon nanotubes.

In the late 1950's a scientist by the name of Roger Bacon discovered a new fiber while experimenting with carbon. However, these fibers were not fully understood until 1991, when a scientist by the name of Sumio Iijima did an extensive study on them and figured out more precisely what they were – carbon nanotubes. Carbon nanotubes are rolled up sheets of carbon, with the sheets being many times thinner than a human hair. Nanotubes with walls that are only one atom thick are called "buckytubes", and are usually about one thousandth of a millimeter across. Carbon nanotubes have the advantage of being as strong as diamond, but without being as brittle.

However, there are still problems other than a just finding a suitable material for the cable. The elevator would have to be located near or at the equator in an area that is both geologically and politically stable. There are very few such places on land that meet these criteria. One solution is to anchor the space elevator on a platform in the middle of the ocean. There are no hurricanes at the equator, and the base could be moveable to avoid any local thunderstorms. Another issue is small pieces of space junk such as bolts and flecks of paint punching holes in the cable. Any holes punched in the cable could be repaired before they became a serious problem. For larger debris such as discarded satellites, the sea base could move to avoid the debris, a feature already necessary to avoid storms. Yet another issue is that the space elevator would be a prime target for saboteurs. A way to protect the elevator would be to set up a one hundred mile radius no-fly no-sail zone around the base.

3.2 Alternative Methods of Space Travel

Although an elevator would be the most efficient way to travel into space, there are many other new ideas that could also work. Many of these alternative methods include some sort of electromagnetic projectile launcher. The basics of all these plans are the same, but they have a few important differences. Electromagnetic launchers work by accelerating some sort of projectile along a track using a high speed magnetic system or a linear motor. The projectile is accelerated fast enough that when it reaches the end of the track, it flies off into space. This track is either vertical or horizontal with the end turned up. One variation of this idea is called the “Launch Loop”, or “Lofstrom Loop.” This consists of a very long track elevated 80 kilometers above the earth. Because the track is so long (1242 mi or 2000 km) to get to the necessary speed, the projectile only needs to accelerate at about 3g, an acceleration that humans can handle. This allows human to be launched without harm because of acceleration. The reason this track is suspended so high above the earth, is so the track doesn't need to be turned up at the end; the projectile would fly off the end of the track, and because of its speed and the curvature of the earth, fly out of the atmosphere and into orbit. The initial cost of such a thing would be between 10 and 30 billion US dollars.



Another method of cheap space travel is a helium balloon or airship. One plan is using a V-shaped airship to get up to about 144,000 feet (approximately 27 miles), where it docks with a space station supported by balloon. The passengers would then transfer to a very long (6000 feet) V-shaped airship that can get to orbit in about five days. A private company called zero2infinity is working on making near-space travel affordable. Their idea, called the “Bloon,” is a large helium balloon that can climb to about 39 km, high enough to see the curve of the earth. The company is selling tickets now at $100,000, and will do its first flights in a 2015.

3.3 Conclusion

At first, the idea for inexpensive space travel was just a dream. Then it was a possibility. Now it is a mission. And in the future, it will be history. The question is, will it work, do we have the technology, and who’s going to be first: America, China, Russia, or another country? On a smaller scale, going up and down is easy, but when you’re dealing with tens of thousands of miles, it’s not quite so simple. When will it happen? Within twenty years? Ten? Five? One thing’s for sure, it will happen.

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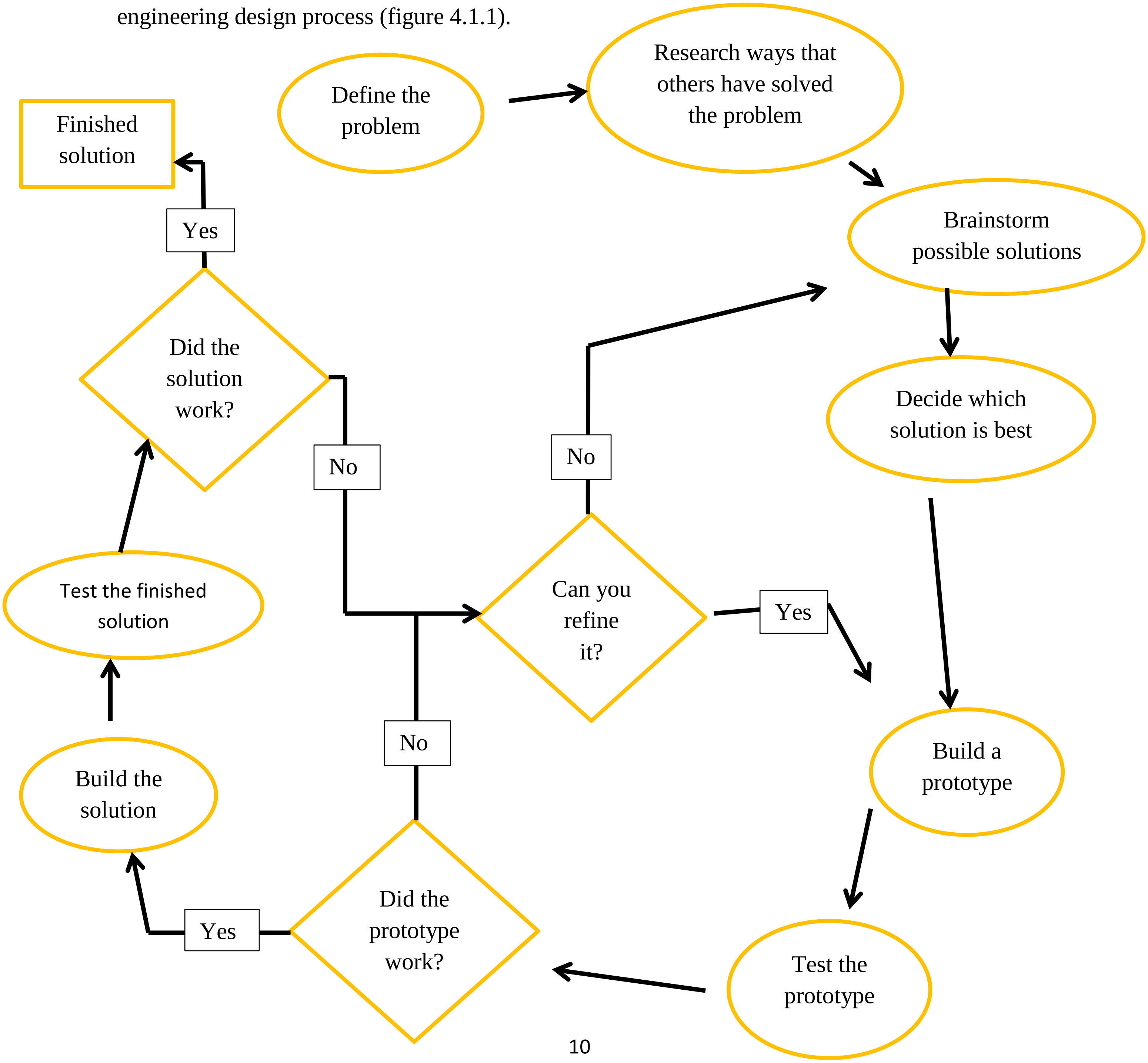
4. ROBOT DEVELOPMENT

4.1 Preparation

Our first meeting was at our church where we met with Jim Walters, who has led the successful Fargo team for years. He explained more to us about BEST Robotics and the engineering design process (figure 4.1.1).



At our next meeting we practiced building with various materials by trying to build a device to pick up trash. We also discussed the team name and the time of future meetings. Our next meeting was in the workshop were we would do most of the building of the robot. We learned about how to safely use tools and how to melt PVC. At this point, we decided on a team name: ARCHER (Anoka Region Christian Homeschool Engineering with Robotics). The next week, after a glorious two hour car ride, we arrived at New London/Spicer for Kick-off. After Minnesota BEST Robotics informed us of the theme, challenges, and rules of WARP XX, they finally unveiled the playing field. We studied the field and examined the kit items, making sure we had all of the items in the returnable kit. We then collected our robot kit, and attended the first breakout session, which was about the notebook. Our team split up for the next two hours and learned about programming, CAD, construction tips, and BEST Robotics presentation and booth. As we left, we were hit be the reality of it all, and that the 42 day countdown had begun.

4.2 Safety Meeting

During the safety part of our third meeting, we talked about our safety rules. We talked about the importance of wearing safety glasses, opening the workshop door while melting PVC to insure proper ventilation, unplugging power tools when done using them, and making sure the tools are off when we plug them in. We also talked about not wearing baggy clothing or sweatshirts with strings, keeping hands and fingers away from running tools, and clamping down pieces being drilled or cut. We also agreed that an adult should always be present while operating power tools.

After learning the safety rules, we learned how to use the tools that we would be used to build the robot. Many of the team used a jigsaw for the first time. Some of the team chose to melt pieces of PVC and flatten and bend them it into shapes. Team members also used a drill with different types of drill bits. One thing we learned is that you cannot do everything by yourself; sometimes you need someone to help you. At the end of our safety meeting after cleaning up, we reviewed the safety rules that we had discussed earlier and each team member signed the safety agreement form.

4.3 Defining the Problems

The day after kickoff, our team met to define the problems and divide the tasks. We decided the problems could be divided into three sections: going up and down the pole, reaching items with our arm, and grasping the items with a hand. We then brainstormed on possible solutions to the problems.

Problems	Solutions
Up and Down	
gravity/weight	lighter robot
stablization	guide wheels, safty wire
preparation and exit time	hinged back wheel
going up and down	hands, **winch**, inchworm, friction wheels, tread with spikes
Reaching	
length (35 inches)	
weight	
extendable (fit with in 2ft box)	use diagonnal (diagonnal of square is larger than side)
stiff/strong enough	
left/right adjustable	? (still a problem)
reach up and down	1 joint for elbow, and either 1 or 2 for shoulder
Grabbing	
shapes (spheres, cylinders, T-shape)	scoop and grabber, **squeezer/dumper** for balls
rotation for T	wrist
grip strength	

One great idea was the squeezer/dumper. It was based upon a tube used to pick up golf balls, and the idea would work great for both picking up the balls and storing them. After defining the problems, we assigned each of the different sections (up and down, reaching, and grabbing) to a different family. The next week we met together and decided that instead of having an arm do everything, we would start with an arm just to grab the balls, and worry about the other items if we had enough time. The development of the various parts is described in the following pages.

5. ROBOT COMPONENTS

While developing the robot, we found that we could divide it into five different sections: the base, the arm, the squeezer/dumper, the winch, and the stabilization system. Dividing the robot into these sections helped to break the formidable project of building a robot into more manageable tasks. We researched the six simple machines, the building blocks of all other machines.

A LEVER is a bar that rotates on a fixed point (fulcrum) and is to make lifting things easier.

An INCLINED PLANE is a slope that makes moving things from one height to anther easier.

A SCREW is an inclined plane wrapped around an axle used to raise/lower objects and hold things together

A PULLEY move a load up, down or sideways. The mechanical advantage is equal to the number of pulleys.

A WHEEL AND AXLE is two wheels on the same axle, making circular motion either easier or faster.

A WEDGE is two inclined planes put together used to push two objects apart.

5.1 Base

Our original ideas all included building a horizontal base to go around the pole. Our plan was to build a squarish "u" shaped base, with a hinged back and locking mechanism to keep it on the pole (figure 5.1.1)

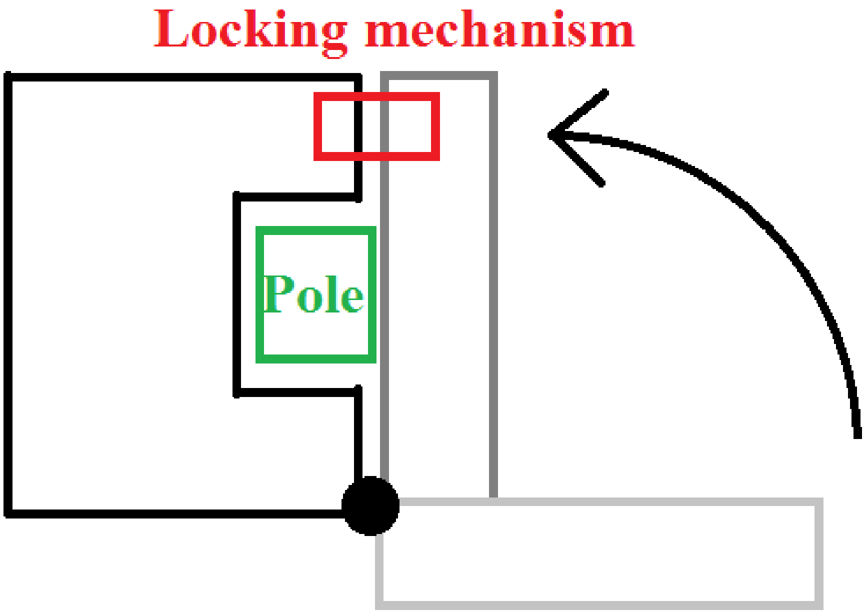


Figure 5.1.1

However, we had trouble figuring out how to keep the robot stabilized, as our base was thin and had few points of contact with the pole. Then we realized that we didn't need to build a horizontal base that was parallel to the floor. It could be vertical and parallel to the pole. This gave us more places to contact the pole, and greatly increased the stability of our robot. We decided that using wheels to guide the robot would stabilize it without creating friction and slowing us down. Our plan was to use two sets of wheels, one on the top, and one on the bottom. Each set would include a wheel on each side, and a wheel on the back, for a grand total of six wheels.

Our new base was going to be shaped in an “H”. Two strips stick inward to hold the stabilization wheels. A basic cardboard model was built, with a stick representing the pulley.

Figure 5.1.2

Figure 5.1.3

The model showed us that the longer would need to be bigger in order to fit the back wheel. The inside would also need to be wider to fit the “brain” (vex controller). With these in mind, a better cardboard model was made that was longer and wider.

We decided to use the 3/8 in plywood to make the base, as it was strong and cheap if a mistake was made. We started by cutting out the pieces (figure 5.1.4), and put them together later. To mount the boards perpendicular to each other, we had the brackets included in the kit, but there were only four of them. Another option was to use blocks of wood in the corner (figure 5.1.6). We decided to use both.

Figure 5.1.4

Figure 5.1.5

Figure 5.1.6

Figure 5.1.7

While looking for wood to use for the mount, we noticed a piece of wood (figure 5.1.7) that was used to cut out the stabilization wheels. The holes in the scrap wood would decrease weight, let the drill get close to the screws, and leave space for the screw heads. The base was built with the plan that the brackets would be added last. However, we noticed that the base was plenty stable without them, and so decided that we didn't need the brackets. The pulley and "brain" (VEX controller) will be mounted between the two forward facing boards.

5.2 The Squeezer/Dumper

The squeezer/dumper is a simple device that was specifically designed to pick up the four inch whiffle balls which are used as cargo balls. During one of our first meetings, we came up with the idea to model the squeezer/dumper after a tennis ball grabber. The first idea for the squeezer/dumper was to use the four inch PVC (included in the kit) to build a tube that would collect the cargo balls one at a time. We realized that instead of using one tube, we could use two side by side tubes to collect both balls at once (figure 5.2.1). The problem, however, with using two separate squeezer/dumper made out of PVC, was that it was too heavy. Our final conclusion was to make one large box(figure 5.2.2) made of cardboard to pick up the balls at the same time. Piano wire was used to let the balls into the box while stopping them from falling out (figure 5.2.3). Making the squeezer/dumper was not an easy task. It took multiple attempts to get the squeezer/dumper the correct size. The final squeezer/dumper (figure 5.2.4) was 15 by 4 ¼ inches, long enough that it could grab the balls whether the field was oriented left or right.


Figure 5.2.1 Two tubes


Figure 5.2.2 Testing the “box”


Figure 5.2.3 Piano wires


Figure 5.2.4 Final squeezer/dumper

5.3 Arm

While designing the arm for the squeezer/dumper we had to look at many things. One of the first things we did was look at the course layout and the height of the balls compared to the height of the base and also the distance from the pole to the balls. We also looked at the cargo bin at Midway Station where he balls had to be placed. What we found was that we needed to have our arm extend at least 7 inches out from the pole in order to get the balls into the cargo bin at Midway Station. The movable part of the arm would need extend the rest of the way to the balls. The arm had to be mounted high enough to reach into the bin, while being low enough to reach down to the balls.

A conceptual prototype was built with cardboard. When our solution was more refined, we built a prototype out of wood (figure 5.3.1) with a joint that had an axle with a pin and a rope with a pulley to move the arm up and down. We found that the location where the rope pulley was attached changed the motion of the arm. We also found out that only about 3 inches of rope needed to be wrapped up on the pulley for the full extension necessary for the arm. We tried installing a guide for the rope but found that it wasn't necessary. There were some angles that the rope had a hard time pulling the arm. It was planned that a small motor would be used mounted to the pulley.

Figure 5.3.1 Arm proto

The arm has two parts and was designed so that a 7 inch piece would be fixed to the robot base and would be about 10 ½ inches up from the bottom of the robot base. When trying to connect to the base, we found that using the inside of the base as guides would be the best solution. This made the base more stable and made the 7” arm part of the base. The 7” length was split into two pieces each 7” long which when left with a gap between them, allows for the other arm to be attached with the pivot point between the two pieces (figure 5.3.2). We also cut out a notch in the arm for the rope connected to the pulley. We needed the moveable part of the arm to extend through the squeezer/dumper, in order to keep the squeezer/dumper stabilized.

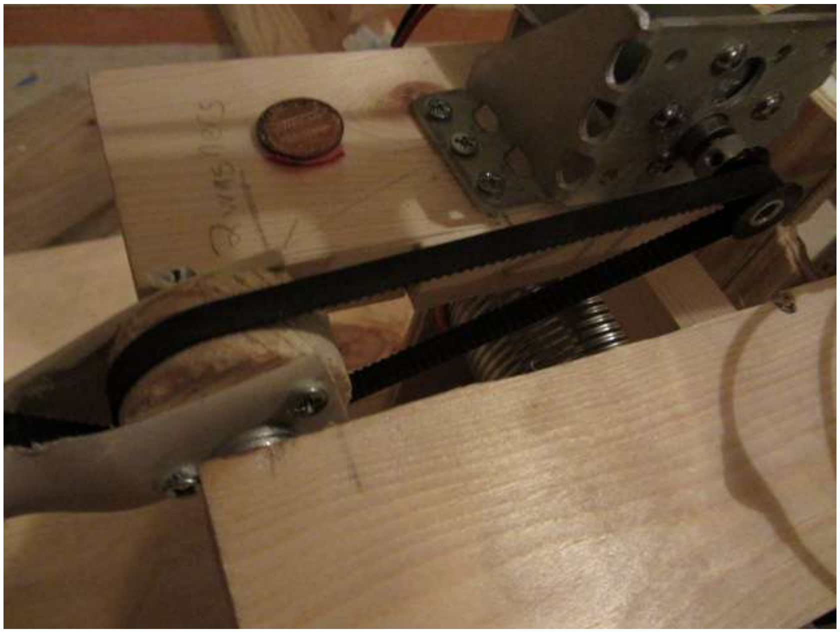


Figure 5.3.2 Arm pulley

5.4 Stabilization

The stabilization of the robot was one of the most important parts of the robot. The first idea for stabilization was to make six separate wheels, and to place three on the top of the robot and three on the bottom, each touching a different side of the pole. We built the wheels by drilling a circle out of a 1x4 piece of wood with a hole-saw. We drilled a hole in the center of the wheel using a ¾ in wood spade. The hole was used to place a piece of ½ in PVC pipe to use as an axle. However, this did not work because it was difficult to drill the circle perfectly straight.

The next idea was to use PVC with a wooden axle. We then realized that we did not need a wooden axle and could just drill a hole in the base to mount the PVC. We drilled a hole in the base to mount the PVC, but it was difficult to drill the hole in the correct place. Some holes were drilled a little bit off and it didn't roll quite right. Many more ideas were brought forward about the stabilization system. Some of those ideas include wood wheels, wood wheels with PVC around them, PVC slides, just PVC wheels, and more. All these designs had the possibility of working, but might be hard to get to work right. One thing that came of it though, was that we found that 1 inch PVC rolled really well with ½ inch PVC as an axle. After thinking for a while, we came up with another idea. This new idea consisted of having a frame made entirely of ½ inch PVC pipe and elbows with 1 inch PVC rollers going around it, that would be screwed to the plywood base (Figure 5.4.1). This idea would be fairly easy to make, easy to get exact dimensions, and would roll well. One initial oversight we made, though, was that we forgot that with the slot in the back of the unistrut, we would either need a wheel over 3 inches in diameter or a wide roller that can span the width of the slot. Discarding the idea of a big wheel to go inside the slot for the time being, we went right to thinking of ways to get the wide roller. This took a while, but eventually we found that if we cut the end off of one of the elbows and drilled out the inside rim so the pipe can go in further, we would have enough room for a wide roller. In addition to that, we also needed to cut off 3/8 off of each elbow to make room for the small rollers that go on the sides of the pole.

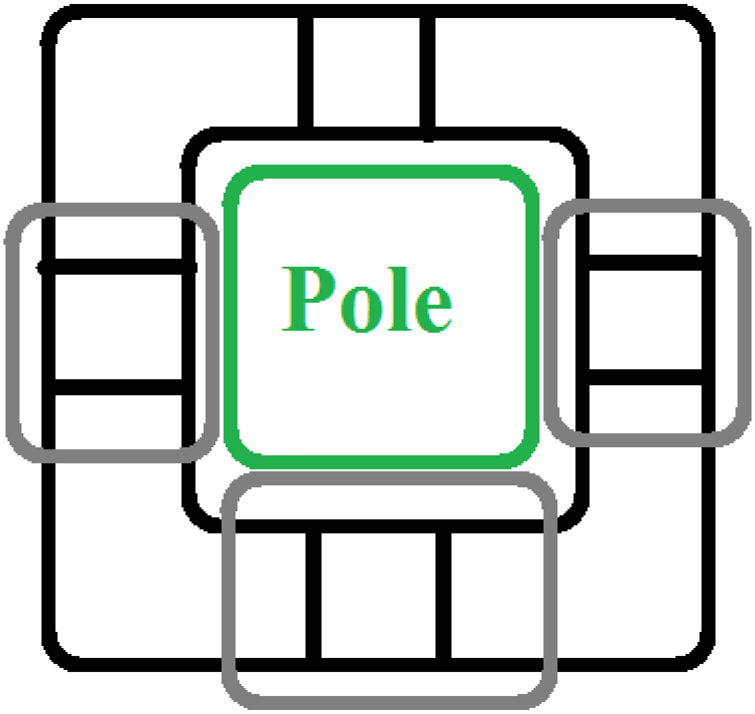


Figure 5.4.1 A top view of our stabilization system (grey is the rollers)

5.5 The Winch

Seeing the game field, it was obvious we needed some way to climb the pole. There were many ideas thrown about for this climbing system. Some of these include a sprocket with teeth that fit in the holes in the unistrut, friction wheels that gripped the sides of the pole, a winch to wind up the string hanging down from the unistrut, and even two “monkey arms” that climbed up hand over hand. After some discussion, we decided on a winch system to climb the “space elevator.” One of the first thing we did was research winches and how they work. We learned that a winch is a relatively simple machine. The basic materials you need are acylinder and covers for the edges. The cylinder is the spool on which you wind the rope. To wind the rope you need a crank or in our case a motor to spin the winch. Now you have a winch which can pull things toward it, or lift something or itself up. What we also learned about winches is that they are used all the time in fishing reels and elevators, like the space elevator. The best part about winches is how they make pulling things easier.

Designing the winch for our robot was a fairly straightforward process, but still had its share of complications. Using some simple math (Speed of cable = 2 x π x Radius of spool x Rotational speed), we figured that with a one inch radius spool driven by a large motor we could climb at 270 inches per minute, with a maximum robot weight of 23.5 pounds. With that speed then, our robot could climb the pole in about 28 seconds. Because the maximum allowed weight is 24 pounds, a spool with a radius as small as one inch would not be necessary unless we had a very heavy robot. If we could get the weight down to 15.6 lbs., the spool could have a 1.5 inch radius; if we could get it to 11.75 lbs., we could have a 2 inch radius spool.

The next problem was what materials to use for the spool and mount. Originally, we were thinking a section of the four inch PVC, or many stacked up wood circles to create the spool cylinder. The first idea, PVC, would be workable, but it had two major problems. First, a spool that big would climb very fast, but would require a very light robot. Second, the PVC is hollow, so something would need to be inserted in both ends so axles can be put in. The other idea, wood, was not given much thought because multiple issues including weight and getting all the circles the same size and shape and connecting them made the idea unfavorable. Another idea that came up was having many pieces of thin PVC bundled together to create a somewhat circular cylinder. While searching around in the kit for something better for the spool, we saw that in the optional kit (things that are allowed on the robot but not included in the kit), it mentioned that three ten ounce soup cans were allowed. Once we obtained a can, we measured it, and found that it had a radius of approximately 1.25 inches. That was a little on the small end, but would definitely work, allowing us to climb the pole in about 20 seconds with a maximum weight of 18.5 pounds. Another plus of this design, is that because the can has a metal bottom, we only needed to make one wooden insert for the open end. Our can plan originally called for using CD's (also in the optional kit) for the walls of the spool, but this was eventually discarded in the final version because it took up too much room and wouldn't really be necessary because of how it fit in the robot base. Having decided the main plan, the next step then, was to actually build the spool.

Building the spool was more difficult and took more time than we thought, partly because our team is young and inexperienced, and partly because the wood used for attaching the can to the motor shaft cracked several times. Figure 5.5.1 to the left is a mount to attach the shaft to the can that is very similar to the one we used. The hole in the center is for the

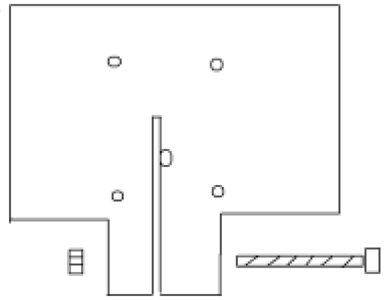


Figure 5.5.1

shaft, and the slot next to it is so that when a machine screw is inserted in the side and tightened as shown, the slot compresses, making the hole smaller, and clamping around the motor shaft. The four other holes are for screws to be driven through into the bottom of the can. To close the open end, we cut and sanded a wood circle the size of the inside of the can (figure 5.4.3). To attach that circle to the can, we drilled three holes in the side of the can and into the wood. Screws were inserted in two of the holes, and an eye-bolt was put in the third one to hold the rope. In the middle of the wood circle we drilled a hole and put in a 2 inch bolt cut out of the 1/4” threaded rod for an axle.

Putting the whole winch assemble into the robot base was quite difficult. We needed one 1.5” diameter hole in one side for the motor to go through and one 1/4” hole for the axle. In the end, we had to take off one side of the base to get it on. Even after we thought it was all finished, there was still a lot of work left, mostly because on its first test, the winch kept on driving after it reached the top of the pole, cracking the wood. To fix it, we had to take a piece of an angle bracket and put it against the flat part of the mount. Once that was done, we finally got our robot to climb up the pole on its own.

Figure 5.4.2 The winch

Figure 5.4.3 Close up of the wooden circle

6. Testing

With all of the parts complete, we met together with the goal of climbing. The base was cut shorter to fit the new stabilization system. One half the arm was attached. Holes were drilled in the base and the winched connected. After hours of fine tuning, screwing, unscrewing, rescrewing, and PVC cementing, we finally got the robot to climb the pole. The whole team was watching in anticipation as the robot gradually moved higher and higher.

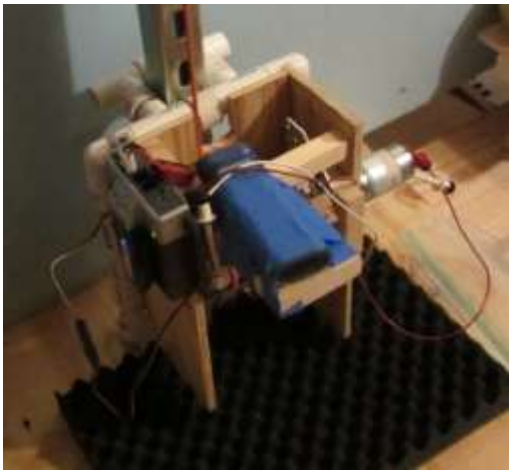


Figure 6.1 Our robot

Figure 6.2 Testing the robot

We spent the next couple days working on improving the parts we had already built. We also finished designing the arm, which we still hadn't completed. The stabilization system was changed to include a faster and better system of mounting the back wheel (figure 6.3). The winch design was working well, however, the piece of wood that mounted the winch to the motor shaft cracked a couple of times, so the design was improved to what we hoped and thought would work. The VEX controller was mounted to a more secure place, and a duct tape pocket was made to hold the battery. A better working squeezer/dumper was also built.

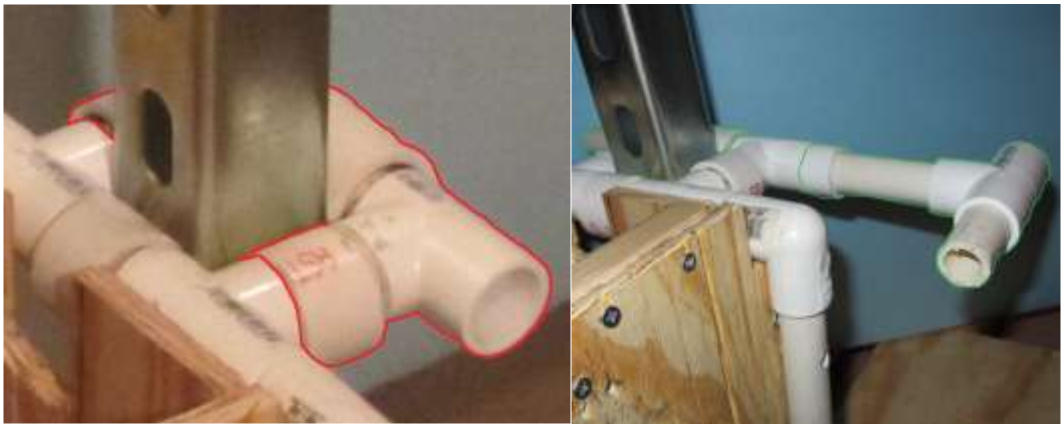


Figure 6.3 The original stabilization had a removable back (red). However, this easily fell off and wasn't the fastest to mount. The improved system had a pin that could be pulled in and out (green). It was faster, stayed on better, and could mount a piece that could hit the summit indicator.

The next wave of revisions after a second test included replacing yet another broken motor mount, changing the stabilization system slightly, and building the arm. The pin that held the back wheel was at perfect location to hit the summit indicator. Plus, it could easily move from left to right (figure 6.3).

The arm was built of half-inch PVC piping. One end was sliced lengthwise in half, heated in a toaster oven, and bent to fit around a wooden wheel (figure 6.4). The PVC was then screwed to the wheel, and a length of the steel rod was used for an axle. Washers were used to keep the arm in place.

Figure 6.4 Arm

Figure 6.5 Arm pulley

The arm was then mounted to a small motor using a pulley (figure 6.5), with one end being the wooden wheel attached to the arm, and the other end being the small pulley included in the kit. The small pulley was mounted to a small motor. This helped to give us the mechanical advantage we needed to lift the arm. After an hour or so, we eventually managed to attach the included belt tight enough to our pulleys. We tested the robot and to our excitement, it managed to pick up two balls, bring them to the top of the pole, and dump them into the bucket. Our whole team was overjoyed. The squeezer/dumper had trouble picking up more than two balls at a time, which is something that had to be fixed. The arm was also the wrong length, however, even with these problems; we felt happy and were close to completing our robot. The pulley later came loose and had to be attached tighter and more securely.

At the next meeting we fixed the arm pulley and cut the arm to the correct length. To allow the squeezer/dumper to hold the balls in better, rubber bands were used to hold the piano wires together (figure 6.6). The stabilization system had to partially be redone, as some of the PVC joints that we had cut shorter were too short, and didn't have enough area to cement the pipe to. We also started mounting a pressure sensor to the top of the robot so that we could program the robot to stop if it got too high. We continued to have problems with getting the pulley tight enough, causing the arm to slip.

Figure 6.6 Rubber bands

In our final meeting before mall day, we fixed all the problems we had left. We fixed the stabilization system so it stayed cemented, and cut it shorter to avoid the bracket at the bottom of the pole. The base had to be modified to fit the shorter stabilization system. The pressure sensor was more firmly mounted, and we tightened (again) the arm pulley. We practiced running the robot as if for competition, and manage to complete everything in two minutes. Seeing as we had extra time, we considered adding a second arm in the week before the competition.

At mall day, we finally got to see if our robot worked on the official course. We realized that the arm for our squeezer/dumper was barely long enough, and hardly got over the edge of the bucket. We saw some of the other teams' robots and noticed one that had a very similar design to our own. We did fairly well, placing first in the mock competition. Also that day, we decided to start work on a second arm to grab the fuel bottles and put them in their correct places. We are currently working the arm, with progress going well. Hopefully, we'll be done by the BEST 2012 WARPXX Competition.