KILLER BEES 33A
ENGINEERING NOTEBOOK
NOTHING BUT NET

Change History

- First draft 16 October 2015

- Second draft 10 December 2015
  - Changed 3.2.4 Motors in Front and Back
  - Changed 3.3.3 Robot Roller Material Wider
  - Updated 8.4 Competition Overview
  - Updated 9.0 Achievements

- Third draft 19 February 2016
  - Updated 8.4 Competition Overview
  - Updated 9.0 Achievements

- Fourth draft 8 April 2016
  - Updated 8.4 Competition Overview
  - Updated 9.0 Achievements

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Introduction

The Killer Bees Robotic students participate in VEX to improve their knowledge and skills of engineering. The Killer Bees have been expanding their involvement in VEX over the past years. Every year they get more students involved and create more teams. VEX helps the students get ready for the other things we do like FIRST Robotics (FRC) which is the main activity that our team participates in. VEX is now becoming a big part to the Killer Bees organization.

1.1.0 Team Members

1.1.1 Perry Outman

I am a senior at Notre Dame Prep, and I am on Team 33, The Killer Bees. This is my fourth and final year being on The Killer Bees Team. This is also my fourth year of doing VEX. I also participate in FIRST robotics (FRC) and in OCCRA. I love this year's game. I think it will be a very interesting game because it's the first shooting game. Teams will have very similar robots and it will be tough to see who the best is. There will be many strategies to come up with and many strategies that people will have to counter. I am the driver of the VEX Team 33A robot, main designer, main builder, and main operator because this year there aren't many functions of the robot to control. I am excited to be back participating with my teammate, James Pilot. I am very excited for this year because I feel like we have an advantage over many of the VEX teams because in FIRST robotics we usually have some kind of shooting game. This year I feel that the Team 33A robot is very competitive.

1.1.2 James Pilot

I am a senior at Notre Dame Prep, and I am on Team 33, The Killer Bees. This is my fourth and final year being on the Killer Bees Team. This is also my fourth year doing VEX. I also participate in FIRST robotics (FRC) and in OCCRA. This is my fourth year of being the main person to program the VEX robot. I am excited to be back participating with my teammate, Perry Outman. This year Perry and I started building and programming the robot early in May and worked on it throughout the summer. This year I feel that the Team 33A robot is very competitive.

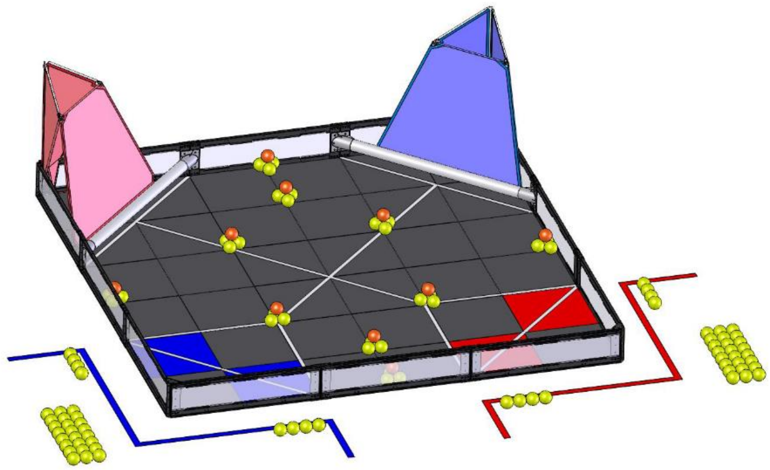
1.1.3 Mentoring

Team 33A mentors five Notre Dame Prepartory VEX Teams. Perry assist with the function of helping the teams build their robots, while James assists the teams with programming. Teams are compied of two Freshmen Teams, an all Girls Team, a Sophomore Team, and a Junior Team. Mentoring for these VEX teams starts in the Summer, meeting every Monday, where teams start build their VEX robots. When the new Freshmen come on the team in September, they will then start to work on building their robot. All teams get to participate in tournaments, especially the annual VEX Tournament at Notre Dame Prep.

1.2.0 The Engineering Notebook

For people who don't know, teams make a notebook of some kind of their whole process of building a robot. By doing the Engineering Notebook, teams learn how to incorporate the design process in building a robot. It not only helps students with writing skills, but helps them how to be organized. It is also used to keep a record of achievements that the students have accomplished.

1.3.0 The Game



Matches are played on a field set up as illustrated in the figures below. Two Alliances – one “red” and one “blue” – composed of two teams each, compete in each Match. The object of the game is to attain a higher score than the opposing Alliance by Scoring your Balls and Bonus Balls in your Low and High Goals, and by Elevating Robots in your Climbing Zone. A bonus is awarded to the Alliance that has the most total points at the end of the Autonomous Period. There are a total of one hundred and four (104) Scoring Objects, ninety-four (94) Balls and ten (10) Bonus Balls, in a VEX Robotics Competition Nothing But Net Match. Each Robot will have four (4) Balls available as Preloads prior to the Match. Each Alliance will have twenty-four (24) Balls available as Driver Control Loads during the Driver Control Period. Thirty (30) Balls and ten (10) Bonus Balls will start at designated locations on the field. Each Alliance has one (1) Low Goal and one (1) High Goal for Scoring Objects into.
(Nothing But Net - Game Manual Section 2 - The Game)

2.0 Requirements and Functionalities

2.1.0 Things a Robot Can Do

In this section of the book we made a list of every single thing a robot can do during a match. We wrote down what the robot can do for playing offense and defense. This is important for the design process because it helps us figure out how to build the best robot to play the game. After we list everything, we rate them 1 - 5 to see what we think the best robot would be able to do, and explain why that robot would do that or not .

2.2.0 Ratings 1 – 5 (1 is bad, 5 is good)

Robot Functionality	**Rating 1-5**	**Explanation of Reason for Rating**
Move	5	If the robot is shooting from the alliance tiles it doesn't have to move, but the robot is limited to the amount of balls in the human player station. If there is also another robot that only shot from the alliance tiles, then one of the robots is useless, so it's better to move in a match. Even if the robot can't score, it can at least play defense.
Collect Balls From Floor	5	We think collecting off the floor is essential because there are more balls on the field than at the human player station. Plus, there are bonus balls to score which are pretty important in a match. We think that a robot that collects off the floor will score more points than a robot than only shoots from the alliance tiles.
Load From Human Player	4	Some robots won't be able to shoot full court, so being able to load from the human player will help out the alliance a lot. Also, it keeps the field open so there isn't a traffic jam.
Shoot From Alliance Tiles	4	We think that there will be teams that can only shoot from up close, so being able to shoot from the alliance tiles is important. Also, it is important for auton because the robot doesn't have to move then.
Shoot From Half Field	2	We think that shooting from the middle of the field is a bad place to shoot because it's the place where the alliances cross to score. The robot would encounter more defense there than anywhere else, which might make it hard to line up for a shot.
Shoot From In Front Of Bar	5	We think this is the best place to shoot because it's super easy to line up, and once the robot is in position, it is nearly impossible to defend it.
Shoot From 18" From The Bar	3	This is a shot that we wouldn't use all that much because it is only necessary if a robot is in front of the robot by the bar then we can shoot over the robot to score.
Push Balls Around	5	Pushing balls around is another important feature because we don't want the balls to go under the robot, so it's best to push them around

		instead.
Shoot Into High Goal	5	This is probably the most important feature the robot can do in this game because it’s the main way to score points in the game. It doesn't matter where the robot shoots from as long it shoots into the High Goal.
Shoot Into Low Goal	2	Shooting in the Low Goal is basically when there's almost no time on the clock, and the robot isn't in position to shoot into the High Goal.
Lift A Robot Up To Elevate	1	We think that elevating a robot is a waste of time because the robot wouldn't have a shooter, so the robot can only score 25 or maybe 50 points.
Self-Elevate On A Robot	1	This is even harder than lifting another robot up because the robot has to be able to lifts itself on the wall, which we think is impossible to do.
Push Robots Around	3	It would be nice to push other robots around so we can get to where we want to go or to mess them up when they are trying to score.
Not Be Pushed Around	4	We think that this is important because we wouldn’t want the robot to move when it is shooting.
Drive On A Robot To Elevate	2	There might be a time where we might drive onto another robot, but it might take long to get on the robot, or to lift our robot up.
Block Robots From Shooting	3	We think that many robots will have shooters that are towards the front of the robot, so we think being as tall as possible will be good to block other teams from shooting.

2.3.0 Types of Robots

In every game that VEX comes out with there are different types of robots that teams can create. Usually, there are about two to four types of robots that teams make in a VEX game. This year there are three types of robots that teams can create this year: An Elevation, Full Court, and a Short Shot Robot.

2.3.1 Elevation

This is a robot that few teams will make because it doesn't score many points for their alliance. The only thing they can do is lift robots up for 25 or maybe 50 points at the end of the match. The robot could play defense, but this game is designed for high points and when a robot is playing defense, it means that their alliance is not scoring as much as it could. We actually predict that there will be no elevation robot in elimination robots at the world competition.

2.3.2 Full Court

This will be one of the popular designs this year because it's one of designs that will score the best in the game. This type of robot will be the most consistent because the robot is going to do the same thing every match. It has the same plan every match, and it's hard to play defense against it because the loading zone is a safe zone. The robot only has to line up once, but this means the human player must be pretty good. The disadvantage is that the robot will have to pick up balls because most robots will finish shooting the human loads before the match ends, and most teams won't be able to do that.

2.3.3 Short Shot

This type of robot is probably the most important type because it has to get all the bonus balls before the other alliance gets them, and this is how games will be determined. The robot will be good at collecting off the floor and dealing with defense. The robot will likely shoot from the middle of the field or in front of the bar. This robot is not going to score as much as the full court shooting robot, but it will get the important points in the match.

2.3.4 Conclusion

From the three types of robots, the full court shooter and short shot robot are much better than the elevation robot. The full court shooter and short shot robots are good, however, the combination of each design will provide us with the best robot possible. We decided on a robot that would be able to shoot from the alliance tiles and a position close to the goal, and be able to load from the human player and pick up from the ground.

2.4.0 Drivetrain

In this section we list what a drivetrain should have this year for this game.

2.4.1 The drivetrain should use no more than 10 motors
2.4.2 The drivetrain should be capable of forward and backward motion.
2.4.3 The drivetrain should be capable of turning in both directions without limit.
2.4.4 The drivetrain should either have 4 or 6 wheels.
2.4.5 The cortex and power expander should be mounted on the drivetrain.
2.4.6 The batteries should be mounted on the drivetrain.
2.4.7 The game object manipulating system should be mounted on the drivetrain.
2.4.8 The drivetrain should be within the size limits

2.5.0 Game Object Manipulator

This section talks about the mechanism that deals with the game elements like the collector, shooter, and human loading device.

2.5.1 The robot should be able to score into the Low Goal
2.5.2 The robot should be able to score into the High Goal
2.5.3 The robot should be able to pick up a ball from anywhere on the field.
2.5.4 The robot should be able to shoot from a specific spot on the field every time.
2.5.5 The collector should hold all four balls.
2.5.6 The shooter should use no more than 4 motors.
2.5.7 The collector should use no more than 2 motors.
2.5.8 The collector should feed the balls into the shooter.
2.5.9 The human loads should direction fall into the collector.

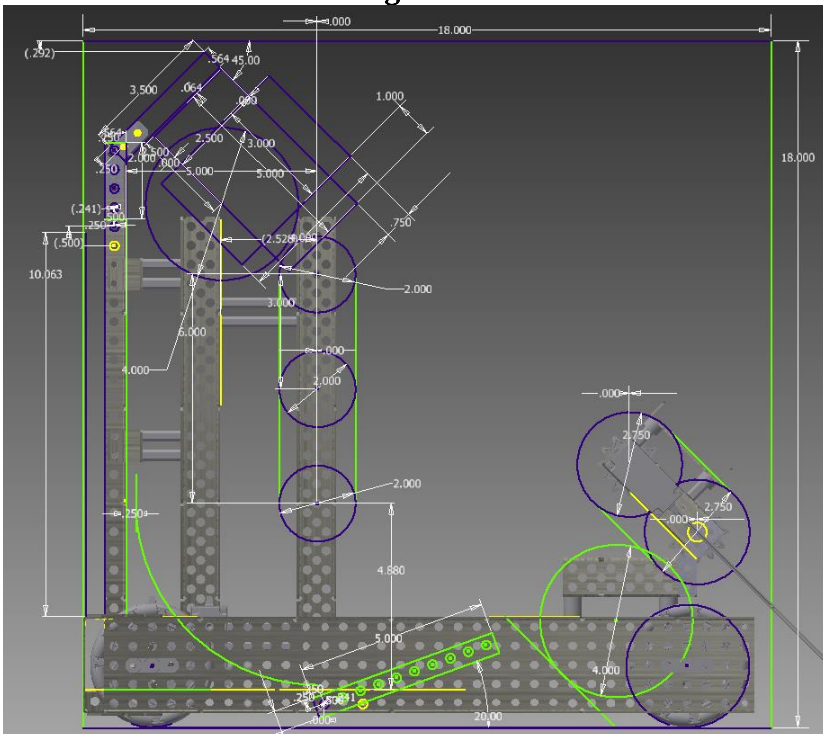
3.0 Design and Building Process

This section is detailed information of how we got to the final design of the robot, and what things we had to improve to make the robot better.

3.1.0 CAD and Sketching

During our design process, we like to create a lot of CAD (Computer Aided Design) drawings, which is a tool that helps us with sketching. If we ever get stuck in designing something and we don't know how to build the robot with the parts, sketching is the way to go. In **Figure 1** below, we see how the sketching tool is used and how useful it is. We use the parts of the robot we have put together so far to help us see what to build next.

Figure 1



3.2.0 Drivetrain

The drivetrain is the main system of the robot. It is the base structure in which all the other systems are built off of, and it is the system that makes the robot move around during the match. The drivetrain holds the cortex, power expander, and the batteries, so the robot can run, and which the center of gravity should be located.

3.2.1 Thin Sides

For this year's drivetrain, we wanted to have lots of room for all the other subsystems that would have to be built on top of it. We decided on making the chassis as thin as possible, and we got each side down to 3 inches, which left us around 11.5 inches to work with. As see in **Figure 2**, we used CAD to see if we designed the sides' right, and so then we can build it right. In **Figure 3**, we measured the side of the drivetrain after we built it with a measuring tape, and it measured out to be 3 inches.

Figure 2

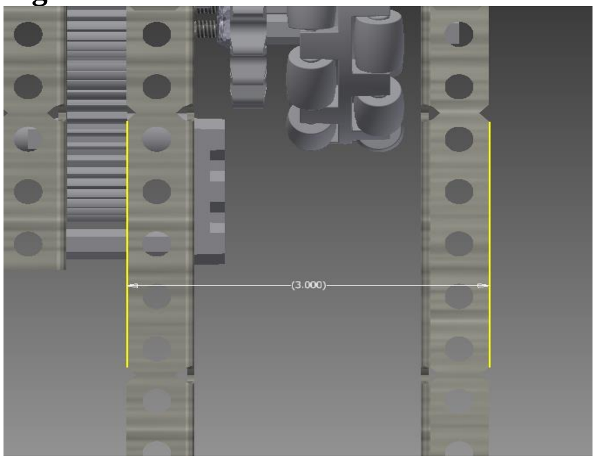
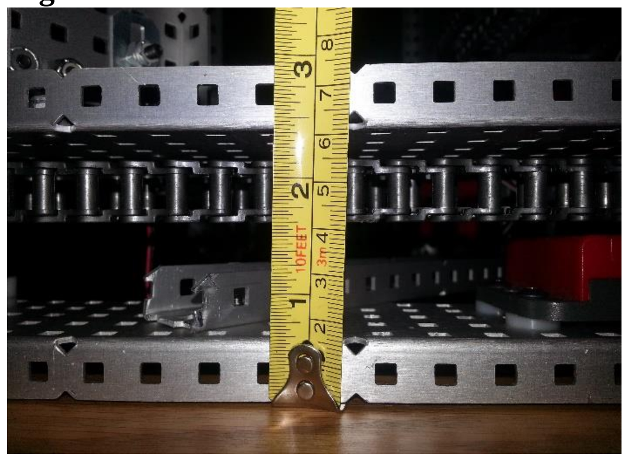


Figure 3



3.2.2 Aluminum Drivetrain

We built the entire drivetrain out of aluminum because the thing that influences speed the most is how much weight the robot is. By making the drivetrain out of aluminum it keeps it light weight, and makes the robot easier to carry from place to place. The lighter the robot is the less time it takes to get to top speed when driving.

3.2.3 U-Shaped

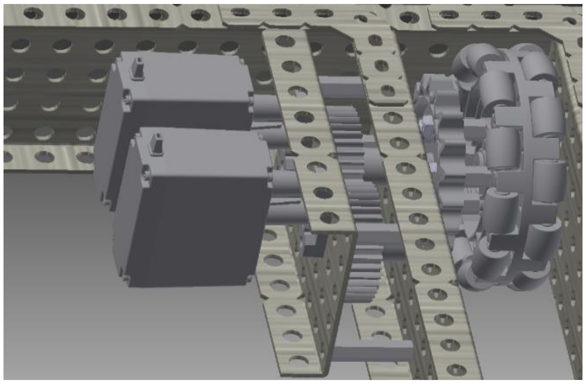
We decided to have a U-Shaped drivetrain instead of an H-Shaped drivetrain because it kept the front and middle of the robot open for the other subsystems. It is very simple to build and to maintain the condition of the robot during the year.

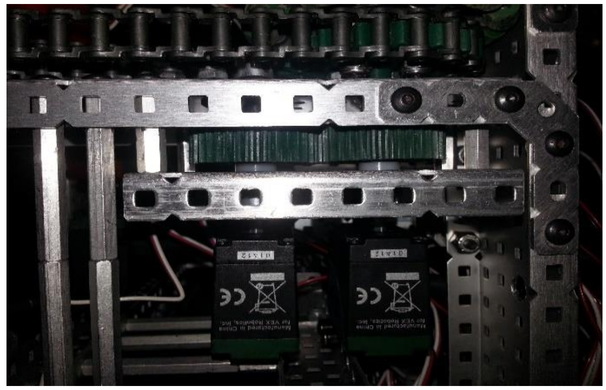
3.2.4 Motors in the Back (Old)

Since we want as much room as possible in the robot, we agreed to find a way to put the drive motors near the back of the robot. It would be hard if we used sprocket and chain for the gearbox, and we didn't want a motor direct driving each of the wheels. A motor located near the front of the robot would take up valuable space. So we used two 36 – tooth gears to tie the motors together and mount them near the back of the drivetrain, as seen in **Figure 4**. In **Figure 5.1**, which is the final design, the drive shaft goes straight into a sprocket and chain, while the other motor supports the main driving motor. This design keeps the drive train tight, neat, and easy accessibility.

Figure 4

Figure 5.1

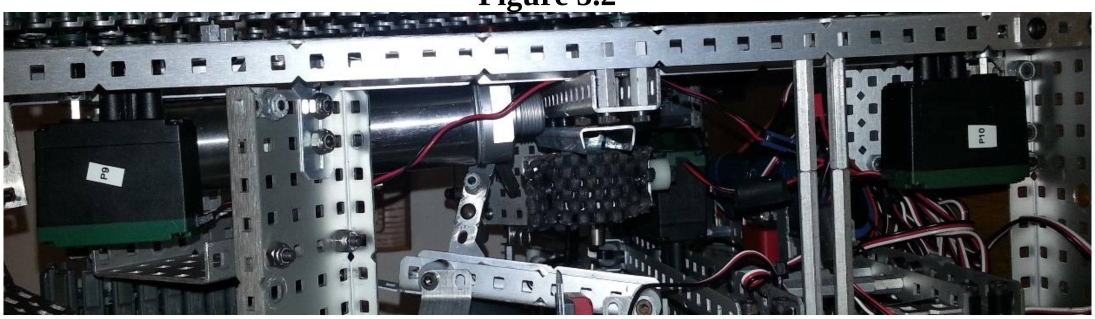




3.2.4 Motors in Front and Back (New Change – 12-10-2015)

After our first competition we had problem with our drivetrain. We learned that by having our motors geared together in the back, caused the motors to actually struggle when running. To fix this, we moved one motor from each side to the front shaft to drive the front wheels as seen in **Figure 5.2**. This made our robot drive better and not stall out during a match. It also makes it to easier to fix things because there is more space in the back of the robot.

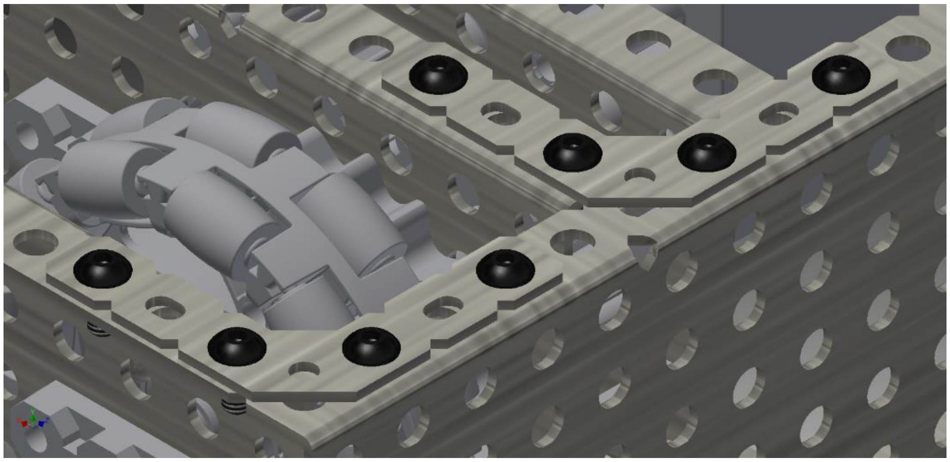
Figure 5.2



3.2.5 Robustness

Since this year's game has a very open field and there is likely defense to occur during matches, we want to have a pretty strong robust robot. To do this, all we did was use a good amount of gussets, as seen in **Figure 6**. We also added a crossbar across the two sides of the robot to increase torsional stiffness, so our chassis won't bend and break.

Figure 6



3.2.6 Pneumatic Stoppers

Since this game has an open field, there will probably be a decent amount of defense played. The robot has omni wheels for our drivetrain and therefore, makes it easy to be pushed around by other robots, at least from the side. To resolve this problem we added pneumatic stoppers to prevent the robot from being pushed around, as seen in **Figure 7 and 8**.

Figure 7

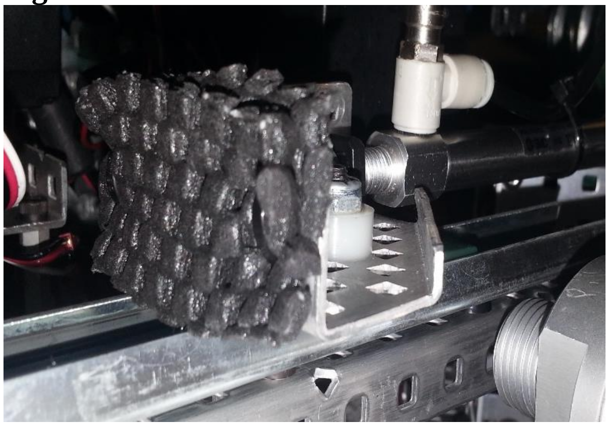
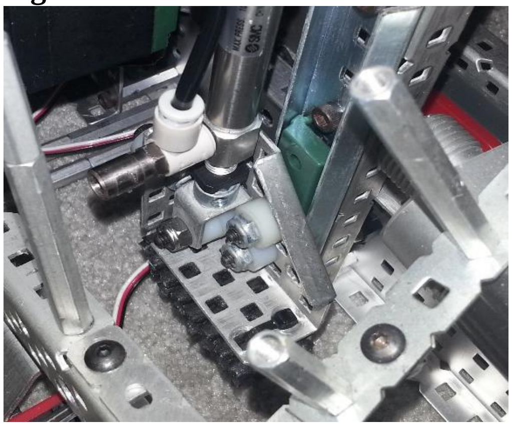


Figure 8



3.2.7 Problems

Surprisingly, we didn't have many problems this year unlike previous years. We really only had one problem and that was the front wheel placement. In our original design for this, the cross pieces that connected each side c-channel was in front of the wheel, as seen in **Figure 9**. When we put the wheels in, we learned that the wheels wouldn't spin because the cross pieces were constraining the wheel from moving. To fix this we just moved the cross pieces behind the wheel, as seen in **Figure 10 and Figure 11**, which allowed the wheel to spin freely and keep the same amount of support to each c-channel. Eventually, we had to move the wheel and the cross pieces back, because we didn't want to worry about not passing inspection.

Figure 9

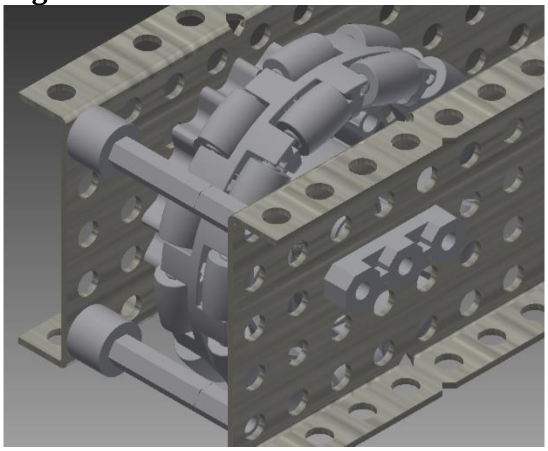


Figure 10

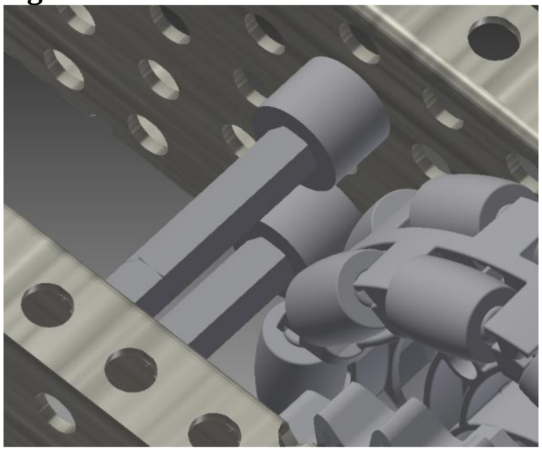
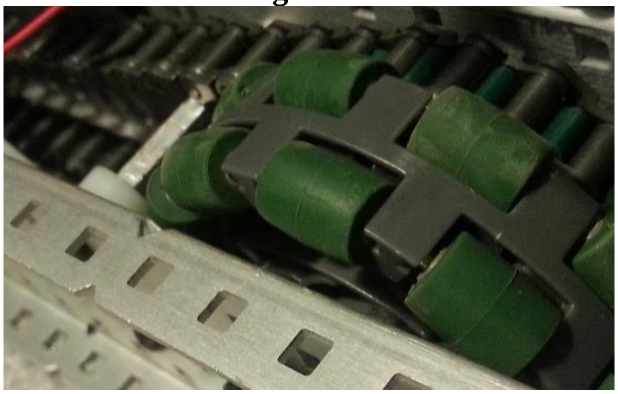


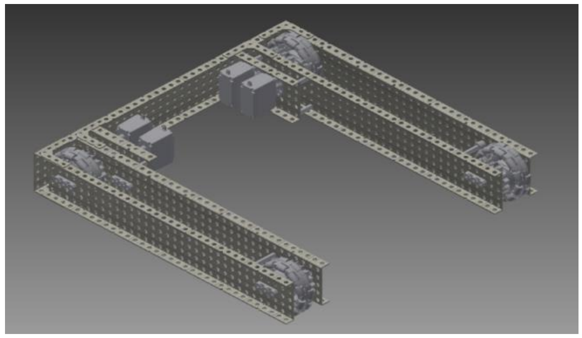
Figure 11



3.2.8 Final Drivetrain Design

The final drivetrain design has 4 motors at high speed to be fast, and we used the least amount of aluminum to keep it light. In **Figure 12**, displays the final design of the drivetrain.

Figure 12



3.3.0 Collector and Loading Basket

The collector is the system that brings the balls into the robot, so it can then go into the feeder system. The loading basket is the area where the human player tosses the balls so then the ball can be funneled into the feeding system.

3.3.1 Mounting the Collector

This was a very challenging feature of the robot to design. It was decided that the collector needed to be on an angle, but also needed the collector to connect both sides of the chassis together. By using the 45-degree gussets, we are able to give the collector the angle we wanted plus, make a place to connect to the chassis, as seen in **Figure 13 and 14**. It is a very strong joint, and it helps minimize torsional stiffness.

Figure 13

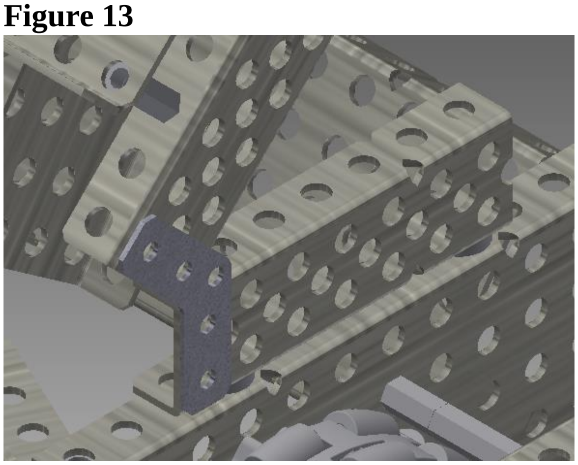
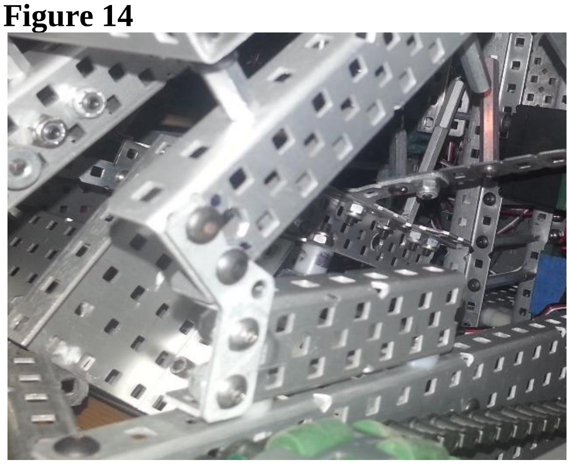


Figure 14



3.3.2 Guiding the Balls In

The goal was to not have the balls get stuck in the chassis. To stop the balls from getting stuck in the chassis, we added pieces of metal to block those areas, as seen in **Figure 15 and 16**. This guides the balls into the collector even if we don't drive straight at the balls. It allows the driver to have some flexibility in their driving imperfection and minimize human error.

Figure 15

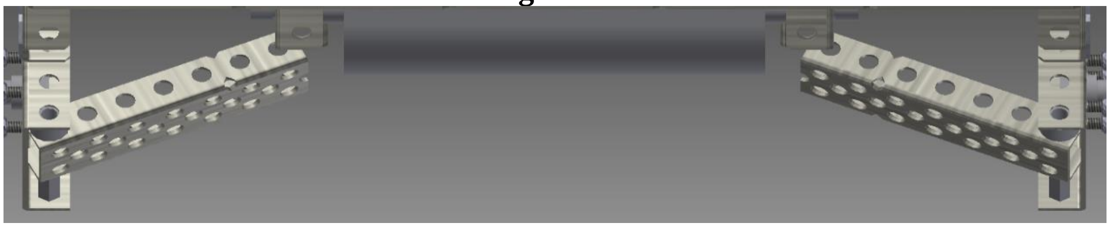


Figure 16

3.3.3 Roller Material (Old)

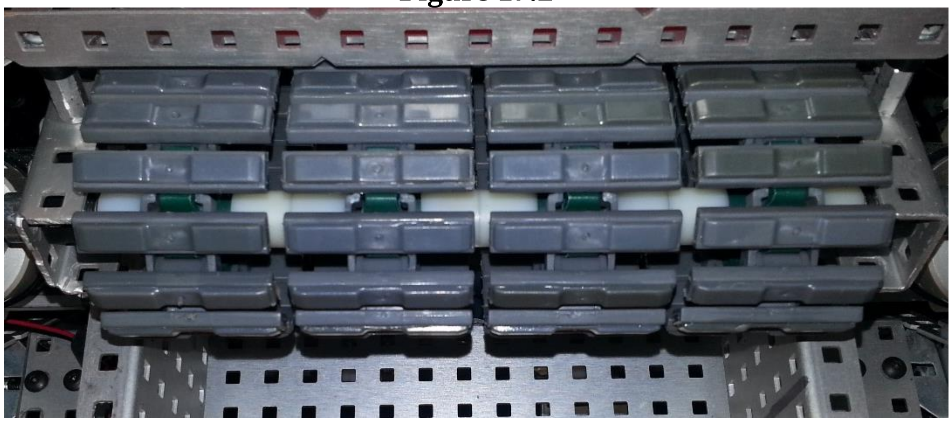
We put a lot of thought in when choosing the material to use for collection. We learned that the tank treads worked the best. This was because it would grab the ball pretty well once it made contact. We didn't use the material with the flaps because it would actually raise our chassis up when the flaps contacted the ball. In **Figure 17.1**, we can see that there are grooves in the treads which allow the collector to acquire the ball easily.

Figure 17.1

3.3.3 Roller Material and Wider (New Change – 12-10-2015)

When collecting from the field, we missed some balls during the matches. We needed to collect balls better, so we added better material that has more friction to grab the balls better. We also made the collector one tank tread wider as seen in **Figure 17.2**. This allowed us to collect better, faster, and lower the amount of human error involved when collecting.

Figure 17.2



3.2.4 Fast Collecting

When collecting the balls at the normal gearing in the motors, the balls would come in really slow. To resolve this issue, we tried the turbo speed gearing and it collected the balls in with perfection and superior speed.

3.2.5 The Basket

We wanted to design this subsystem the last because it had to fit around the more important subsystems. After we designed the main subsystems, we had enough room to make a basket for the balls that would mount on the collector. The basket would be on a 45-degree angle, so the balls would roll into the feeder nicely, as seen in **Figure 18**. We tried our best to keep it light weight by using standoffs to guide the balls to the feeder instead of using more c-channel. An example of this is in the CAD model in **Figure 19**. The basket design makes it really easy for the human player to throw the balls in, and it is easy for anyone to learn.

Figure 18

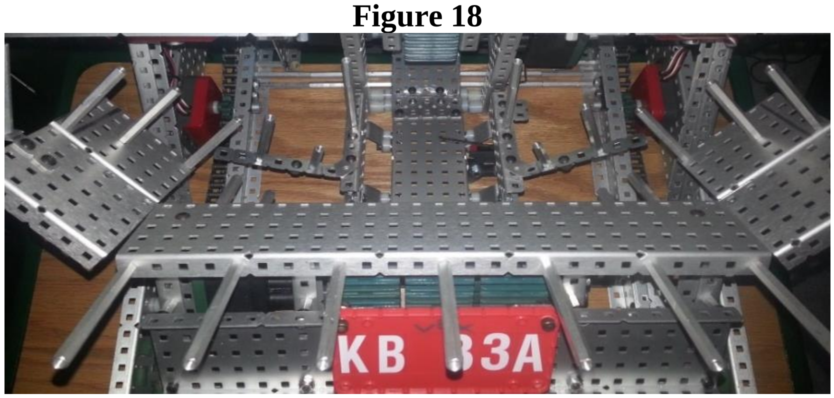
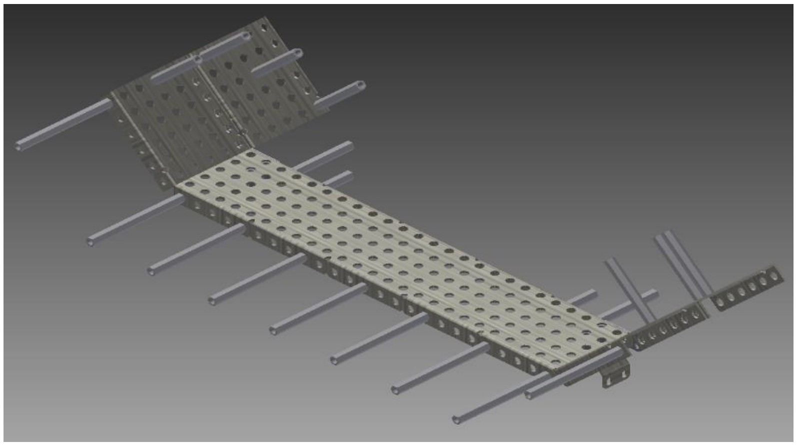


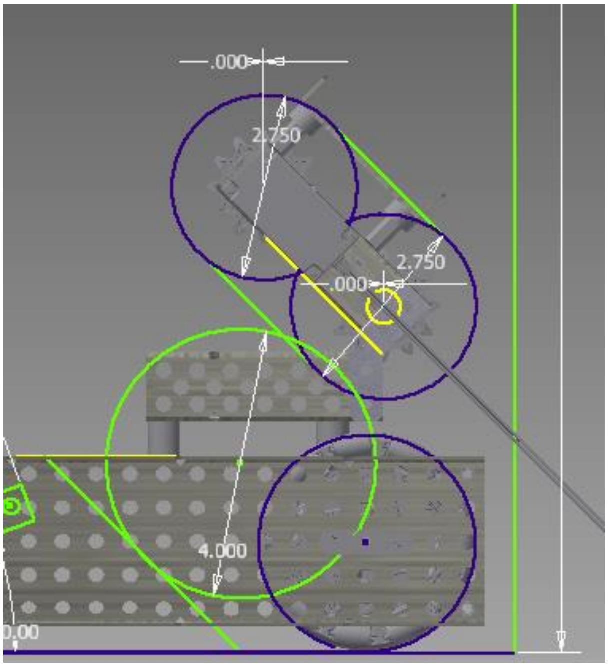
Figure 19



3.3.6 Problems

There were a few problems in designing the collector this year. The problem was trying to get the angle and pinch right on the ball. We spent a lot of time in CAD trying to figure out the right pinch on the ball, and the height of the collector. If we didn't get the height of the collector right, then every time we collected a ball, the front of the robot would lift off the ground a little bit. This then will make the robot's wheels come off and lose traction. **Figure 20** is a great example of how we tested to see if the pinch is right and the height is right on the collector.

Figure 20



3.3.7 Final Collector and Loading Basket Design

The final collector design has only one motor at turbo speed to collect really fast, and the basket is passive, which uses gravity to feed the balls into the feeder. The collector is on a 45 degree angle and has about a ¼ inch pinch. In **Figure 21**, we can see the final design of the collector, and in **Figure 22** we see how the basket attaches to the collector on a 45 degree angle.

Figure 21

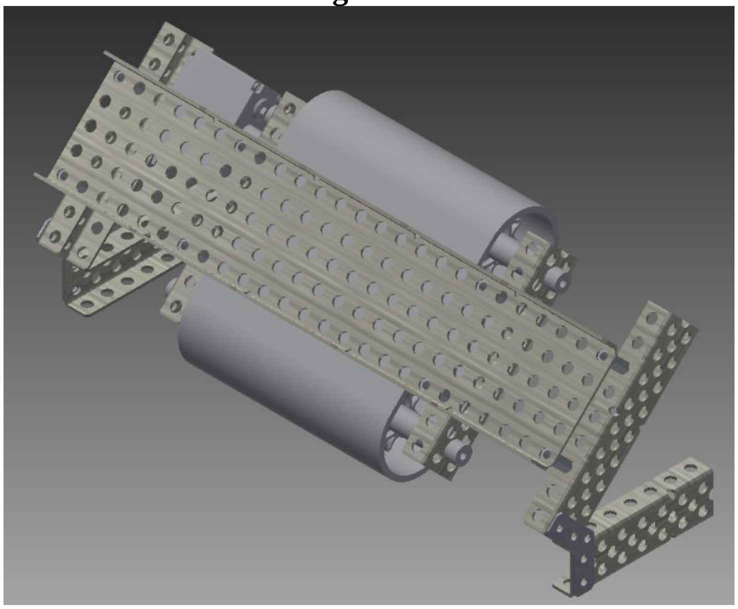
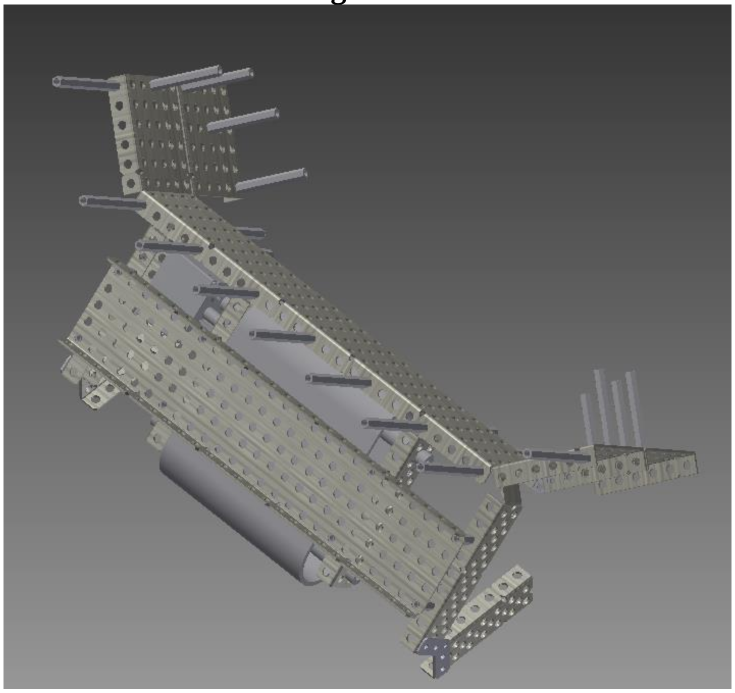


Figure 22



3.4.0 Feeder

The feeder is the system that organizes and holds the balls before they are loaded into the shooter.

3.4.1 Mounting

We wanted the feeder system to be placed in the back of the robot because the shooter will be mounted on top of the feeder. We wanted the shooter to be as far back as possible. This will allow the shooter to never be blocked by other robots. It was really hard to figure out how to mount the system because there's almost no place to mount it. In the end we were able to use the gravity feeding mechanism and the back of the chassis to mount the feeder. After we mounted it, as seen in **Figure 23 and 24**, it was very strong and wouldn't move anywhere. That was another challenge we overcame.

Figure 23

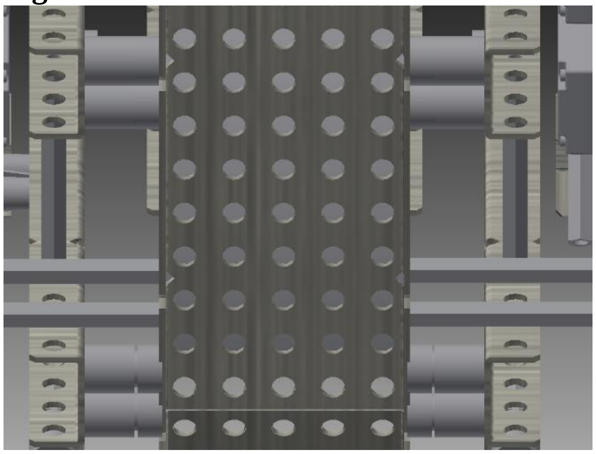
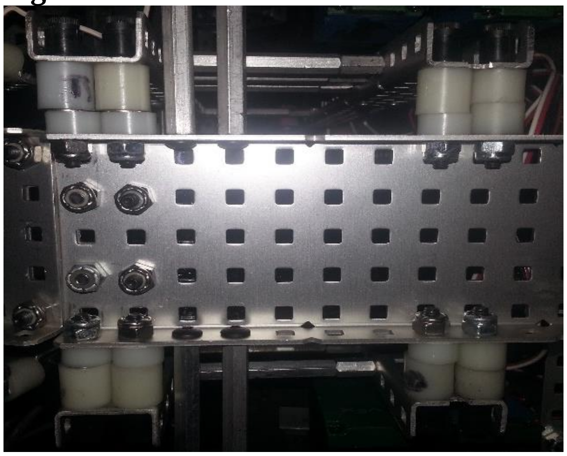


Figure 24



3.4.2 Roller Speed

Just like the collector system, the regular gearing was too slow at moving the balls through the feeder. We did the same thing to what we did to the collector and used the turbo gear to speed up the feeder.

3.4.3 Polycarbonate Guides

We needed to be able to move the ball from a horizontal direction to a vertical direction, so we made polycarbonate guides, as seen in **Figure 25**. We spent a lot of time sketching in CAD to figure out the measurements for both polycarbonate guides. These guides are essential for the robot and if they are designed wrong, then the robot won't work. The robot has two polycarbonate guides. One guide is located at the bottom of the feeder where the balls come in and get organized, as seen in **Figure 26**. The other guide is at the top of the feeder, where it guides the balls in the shooter, as seen in **Figure 27**.

Figure 25

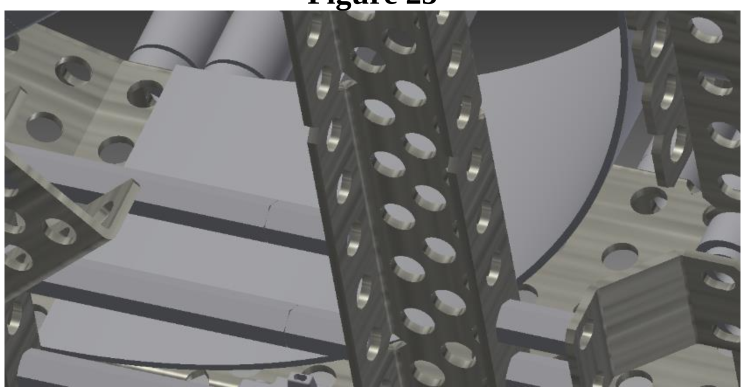
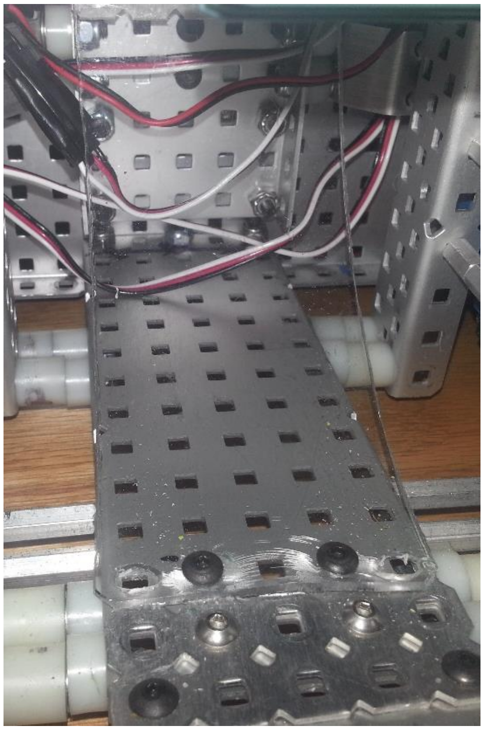


Figure 26 **Figure 27**



3.4.4 Using Gravity

This part of the robot connects almost every subsystem together. After collecting the balls, the balls travel down this piece of metal into the shooter. The great feature about it is that it doesn't need motors or pneumatics. It uses gravity, which then the balls roll down from the collector, as seen in **Figure 28 and 29**. When the human player loads balls, the basket guides the balls into it. The gravity feeding mechanism can holds 2 balls, and the balls are then always ready to be taken into the feeder. It also is where the feeder is mounted, so it carries a lot of importance.

Figure 28

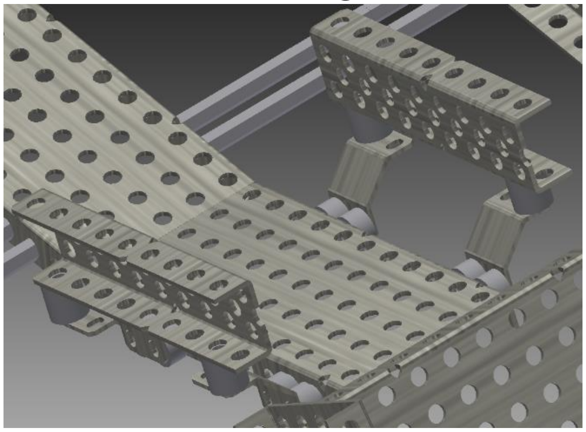
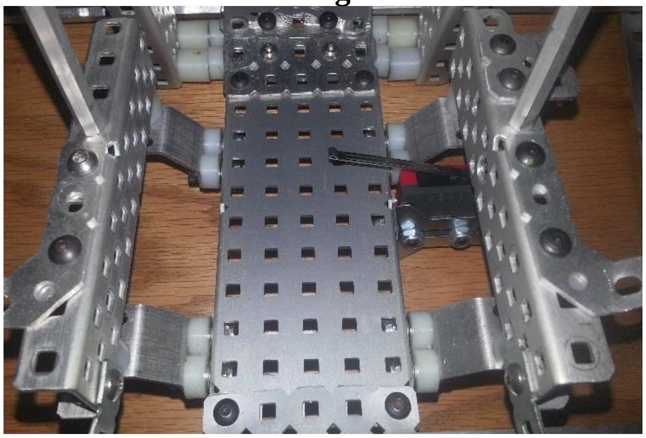


Figure 29



3.4.5 Type of Roller

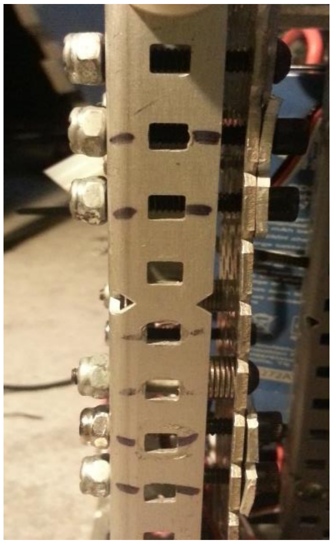
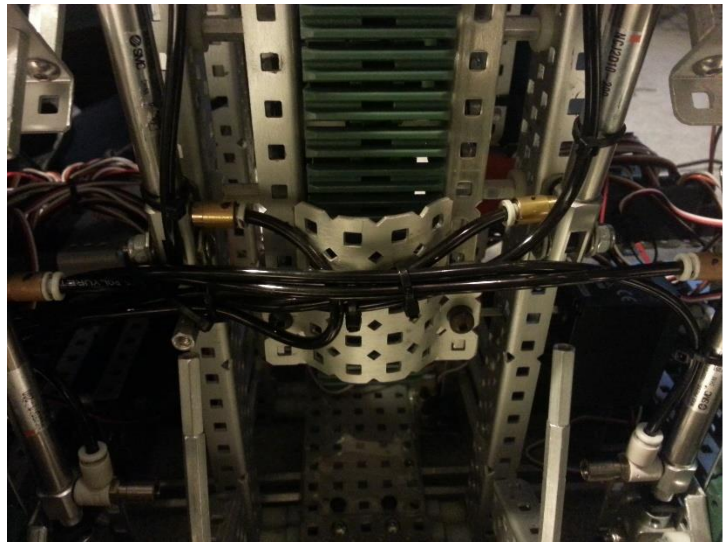
Just like the collector, we decided on the same material, the tank treads. It moves the balls up to the shooter very well and feeds the balls consistently into the shooter. In **Figure 30,** it shows that the grooves in the treads will get good traction on the ball to feed it into the shooter.

Figure 30

3.4.6 Problems

There were big problems in the feeder design, because we didn't realize that some parts of the feeder had to be designed with precision. One problem we encountered, was trying to find the right pinch on the ball while feeding it. This was because the chain has different amounts of pinch at different points in the feeder. To correct this, we had to add plates at certain points on the back piece of the feeder to keep the pinch the same throughout the feeder. We also had trouble getting the regular pinch down too. We had to get real precise with how much we needed to move the back metal plate. To get really precise, we used lots of washers to find the right amount of pinch that was perfect for feeding, as seen in **Figure 31**. We also had a problem when we were putting the pneumatics in. When running the feeder, the pneumatic tubing was rubbing against the treads and making it a little slower. Therefore, we put in a metal plate to protect the feeder, as seen in **Figure 32**.

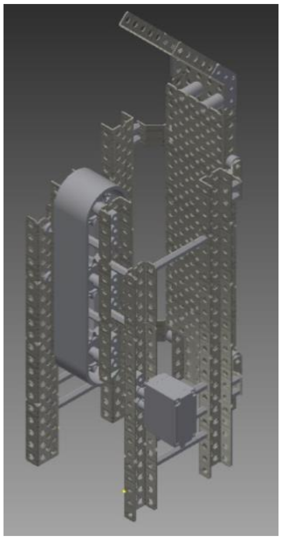
Figure 31 **Figure 32**

3.4.7 Final Feeder Design

The final feeder design, as seen in **Figure 33**, only uses one motor at turbo speed to collect and feed fast. Gravity brings the balls into the feeder so it saves motor and weight. The feeder is a tower that brings up the balls to the shooter, so we can see how many balls we have and keep the balls organized.

Figure 33



3.5.0 Shooter

The shooter is the most important feature a robot can have in this game. It is the main type of mechanism used to score the balls.

3.5.1 4-Wheeled Shooter

After prototyping, we decided that the two wheeled shooter was the best shooter to use in this game, as seen in **Figure 34 and 35**. The four wheel shooter is best because it requires less speed and has less wind up time to shoot the next ball. It is also easy to feed in to and it is easy to maintain it.

Figure 34

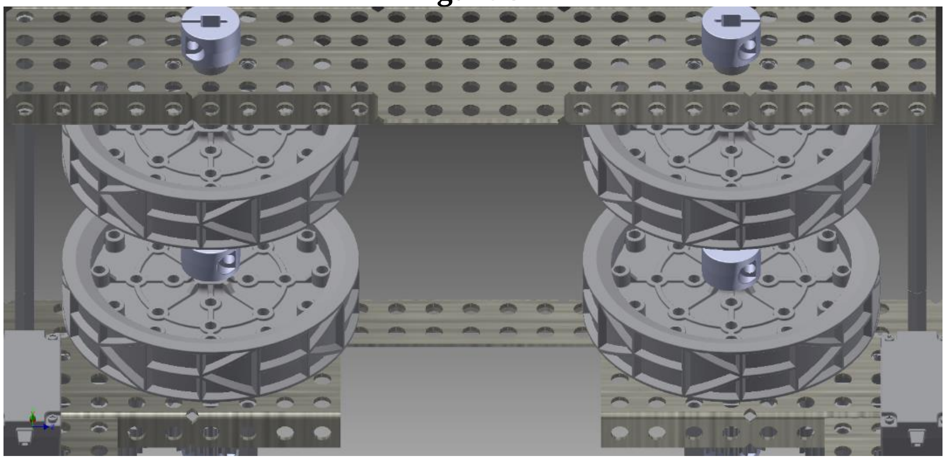
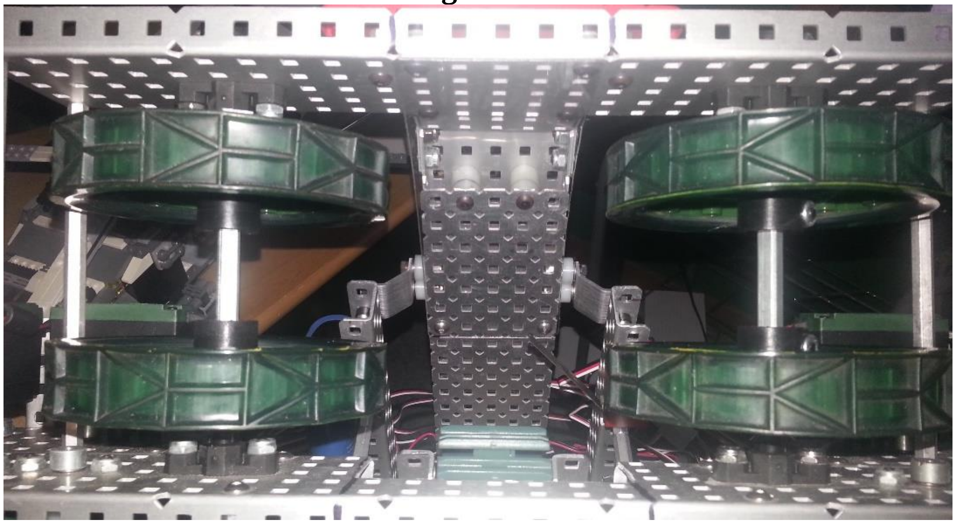


Figure 35



3.5.2 Motor and Gearing Placement

The motor and gearing placement was really important in the design of the shooter, as seen in **Figure 36 and 37**. We wanted the motors and gearing to be mounted on the side of the shooter instead of the front of the shooter. We didn't want the motors and gearing to stick out in front of the shooter because it takes up a lot of critical space. If the motor and gearing where in front of the shooter, we would have a harder time finding a way to human load. Therefore, by mounting the motors on the sides, because we had room on the sides, it wasn't going to interfere with other systems.

Figure 36

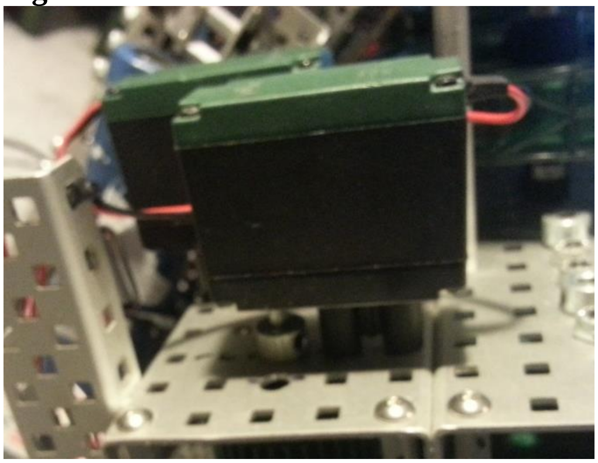
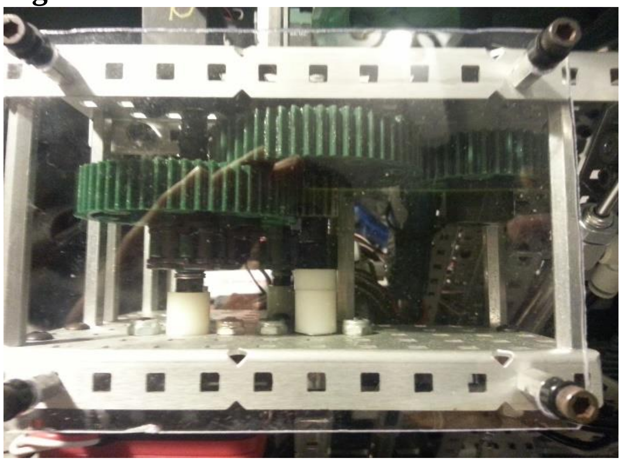


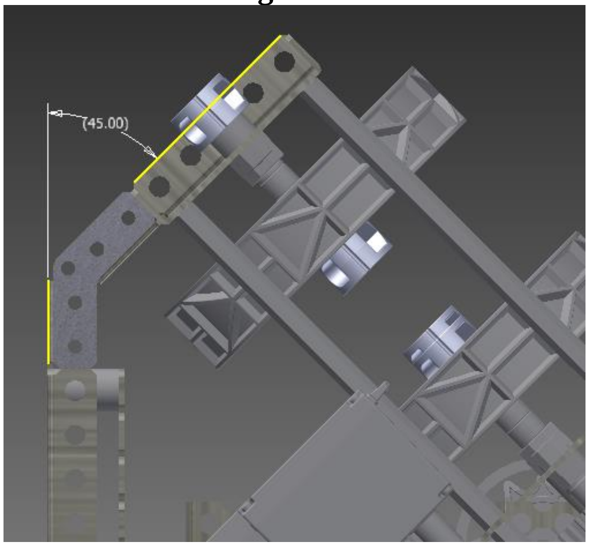
Figure 37



3.5.3 Angle

When designing, we agreed on having an angle for the shooter to be in the middle range, so we picked 45 degrees, as seen in **Figure 38**. It's a good angle because the robot is able to shoot from anywhere on the field and score. It also gives the ball a nice arc to it, and for some shots, the power is the same as another shot.

Figure 38



3.5.4 Mounting

Figuring out how to mount the shooter on a 45 degree angle was tricky, but in the end we found a way. We used the 45 degree gusset to connect the top of the shooter to the top of the feeder, as seen in **Figure 39**. We also had to cut out parts of the top of the shooter to connect it to the feeder, as seen in **Figure 40**. We then connected the ends of the shooter to the drive train to give it more support. The hardest thing we had to do was cut out part of the bottom of the shooter, so we could get the feeder tread in. This could then feed the ball into the shooter.

Figure 39

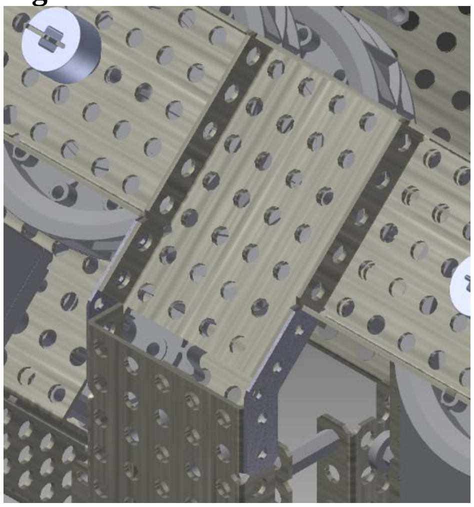
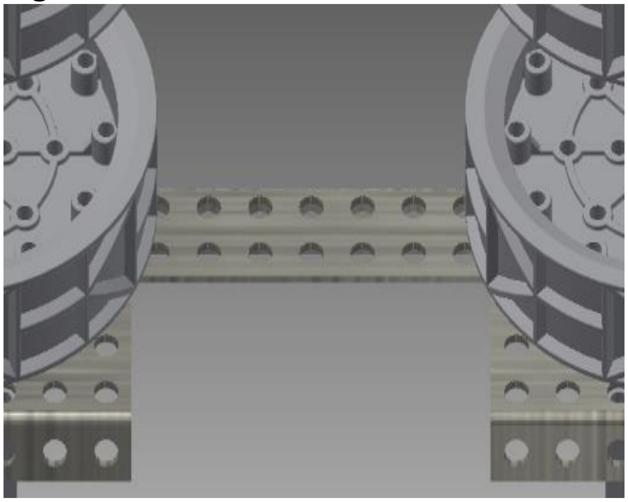


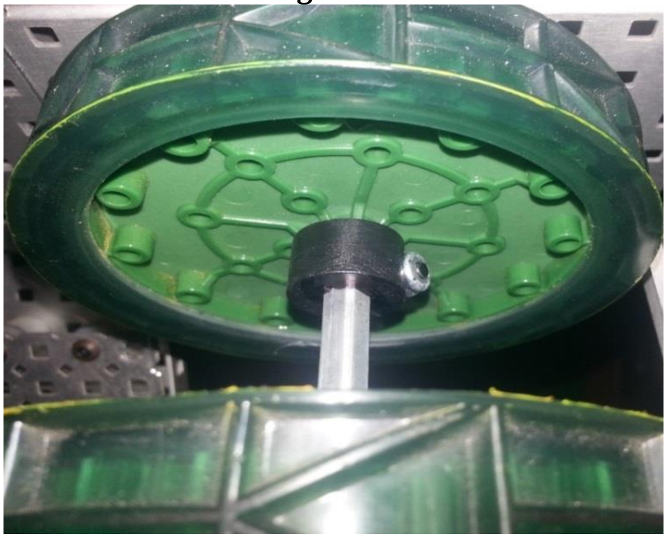
Figure 40



3.5.5 High Strength Shafts and Wheels

We did some different things than what most teams would do with their shooters. We used high strength shafts instead of the normal regular shafts, as seen in **Figure 41**. The reason for this difference is that the regular shafts, when the wheel is on it, have more play with the wheel than a high strength shaft. We wanted to have use 4 inch wheels for the shooter, but none of them have the right hole for a high strength shaft. Instead of using the rim of the wheel, we used an 84 – tooth gear which is around the same size as the rim of the wheel. We just put the tire on the gear and now we have the right hole for the shaft while keeping the same size of the wheel. We used four wheels on two shafts because it makes it so easy to find the right pinch on the ball. We, therefore, only have to change the spacing on the shaft instead of moving the shaft another hole to the right or left.

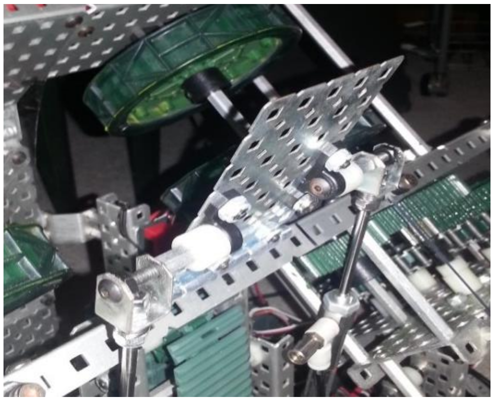
Figure 41



3.5.6 Problems

The only real problem we had in the design of the shooter is getting the shooter to shoot at its maximum potential. It took a lot of fiddling to make work proficiently. Every hole that a shaft went through, we drilled a hole that's about a quarter of an inch and for the high strength shafts we drilled about a half inch hole. This allowed the shafts to spin at their full potential because we got rid of lots of friction. We then greased up all the gearing to help the gearing spin better. After we did all that, we ran it for about a half hour, and it's now at its max potential. The next problem we had with the shooter is that our short shot on the bar wasn't making all the shots. The reason for this was that the balls kept hitting the bar instead of going in the goal. To correct this, we made a plate that is actuated by pneumatics to flip up and redirect the balls into the goals, as seen in **Figure 42 and 43**. This gives the shooter more control over the balls for the short shot and makes the shots super accurate.

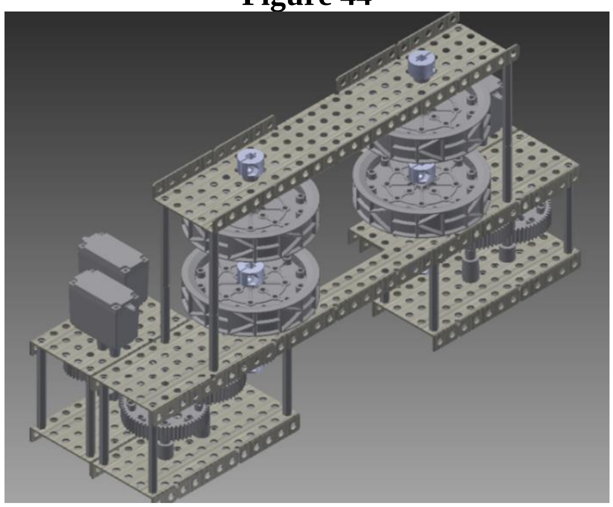
Figure 42 **Figure 43**

3.5.7 Final Shooter Design

The final shooter design uses 4 motors with regular gearing, with two running each wheel, as seen in **Figure 44**. We use 4 inch tires on an 84 – tooth gear with a high strength shaft. The gearing for the shooter is 25:1, and we have 4 different shot ranges.

Figure 44



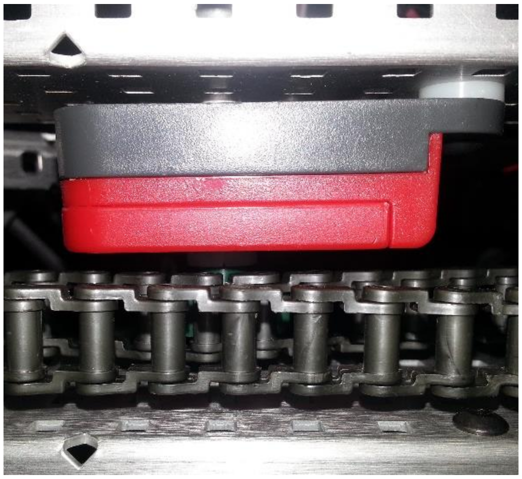
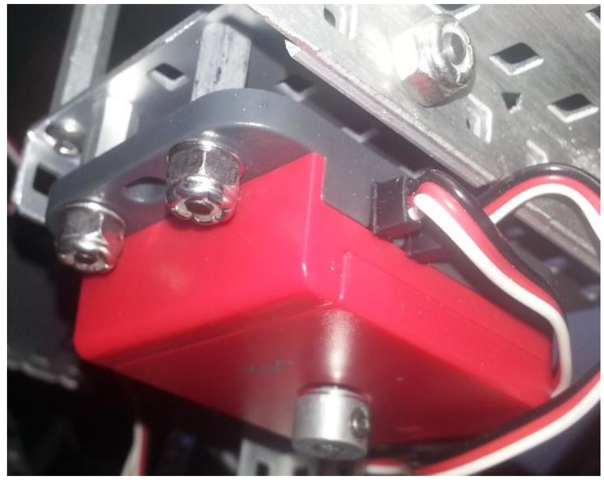
3.6.0 Sensors and Code

In this section we talk about what sensors were used on the robot and what they are used for in helping the robot get better.

3.6.1 Encoders

Encoders give feedback of a mechanism when it is move or running. We use these sensors in our drive train, as seen in **Figure 45**, so we can tell how far we want to travel in auton, and to help us not be pushed from the front or behind. We also have encoders on the shooter, as seen in **Figure 46**. This is the reason why we have a good shooter. The encoders allow us to read how fast the shooter is going, to see if one side is faster or slower than the other, and to minimize the time between shots.

Figure 45 **Figure 46**

3.6.2 Limit Switches

Limit switches are the sensors make the balls really organized and shoot consistently into the shooter. We have three limit switches on the robot, in before the feeder, in the middle of the feeder, and just at the end of the feeder. When a ball triggers the bottom limit switch, as seen in **Figure 47**, the feeder automatically moves it up a little bit. When a ball triggers the middle switch, it doesn't do anything because it's just there to tell that there is a ball there. When a ball triggers the last limit switch, as seen in **Figure 48**, it stops the feeder and waits until the shooter gets to the right speed to shoot. This process keeps the balls organized and it's another mechanism that the driver doesn't have to control while driving.

Figure 47

Figure 48

3.6.3 Potentiometers

People probably are wondering, what do you need potentiometers for? The answer is that we used them to select what auton we want to run. We set a certain degree to an auton and just spin a shaft to go to that degree. It's easy and potentiometers don't cost that much money either.

3.6.4 Problems

We do have some problems with the sensors at times. We then have to hurry and fix them so we can get the robot working again. One problem that occurred was that we kept breaking the metal parts of the limit switches off. To fix that problem, we bent the metal piece in a V, so that no matter what direction the ball is going, the limit switch won't break. We also had trouble in reading the shooter because we couldn't get a reading from certain shafts on the shooter. To fix this problem, we had to find the shaft that wasn't too slow or too fast, so the encoder could get a good reading from the shooter.

3.7.0 CAD

In designing the robot, we use CAD software to create and design the robot in a 3D virtual universe. We used the CAD software called Autodesk Inventor Professional 2015. We created every system in CAD, and this enables us build the robot faster. From the pictures below a person can see the process of designing the systems from the drive train to the entire robot, as seen in **Figure 49, 50, 51, 52, 53, and 54**

Figure 49

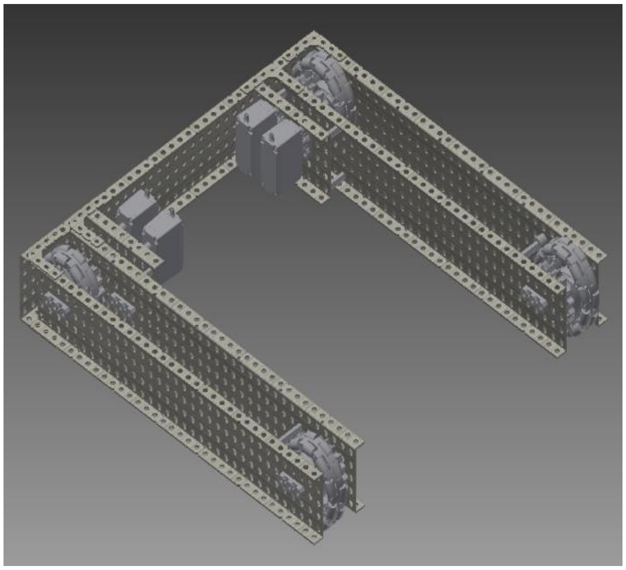


Figure 50

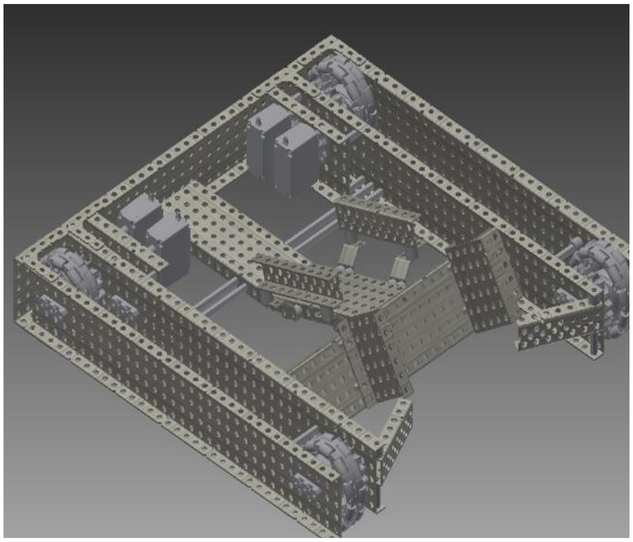
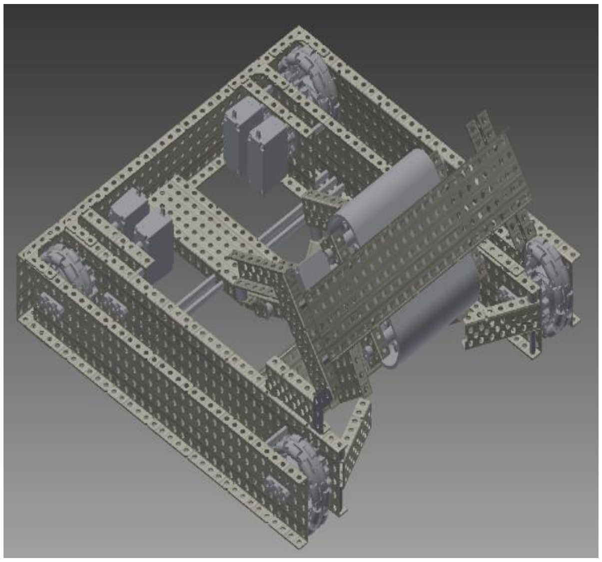


Figure 51

Figure 52



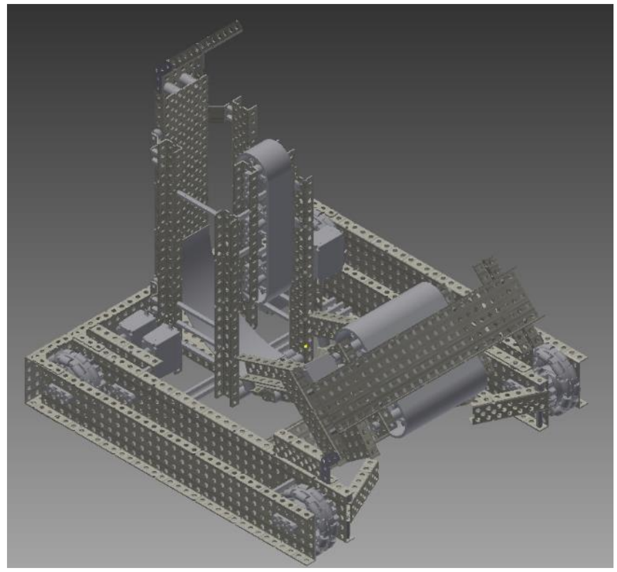
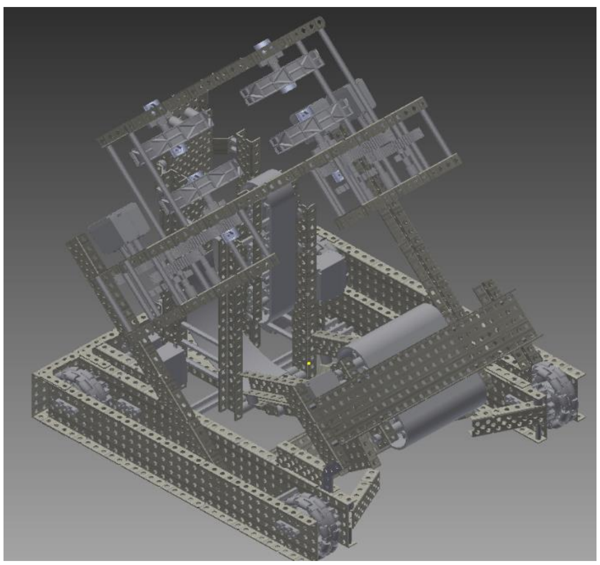
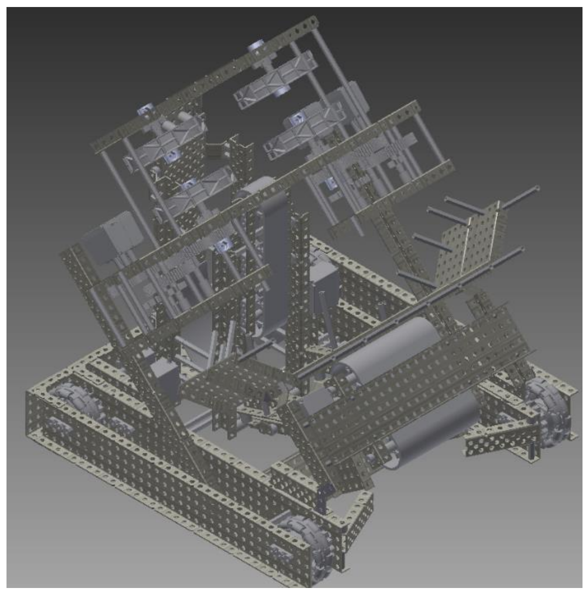


Figure 53

Figure 54





4.0 Alternate Designs

In this section, are some alternative designs that we decided not to use in the final design of the robot.

4.1.0 Chassis and Drivetrain

4.1.1 2-Speed Drivetrain

This type of design would allow us to be able to push teams around while being fast at any time we wanted, as seen in **Figure 55, 56, and 57**. It is, however, complicated to build because it also involves pneumatics to make the system work. We also would put the system in the back of the robot to save space for the other systems. If we had this system instead of a simple high speed drivetrain, we would have a problem deciding where the cortex, power expander, and the batteries would go. Also, we would have to spend more time maintaining this drivetrain than the high speed drivetrain.

Figure 55

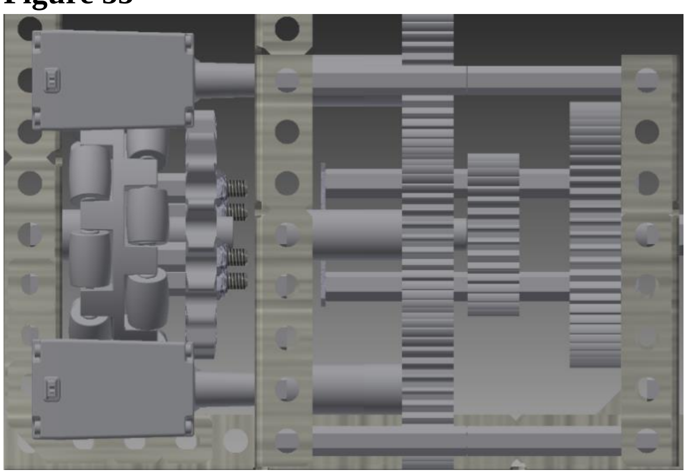


Figure 56

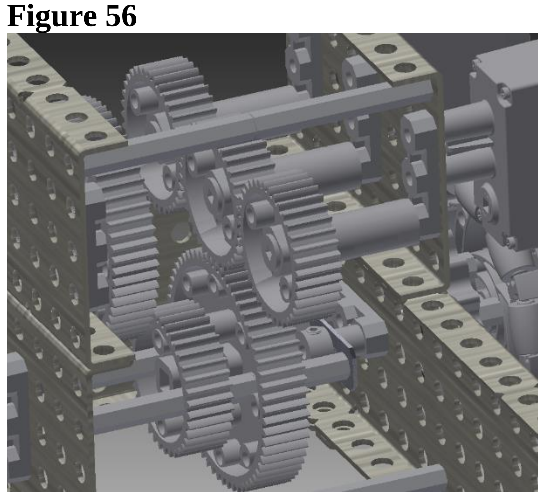
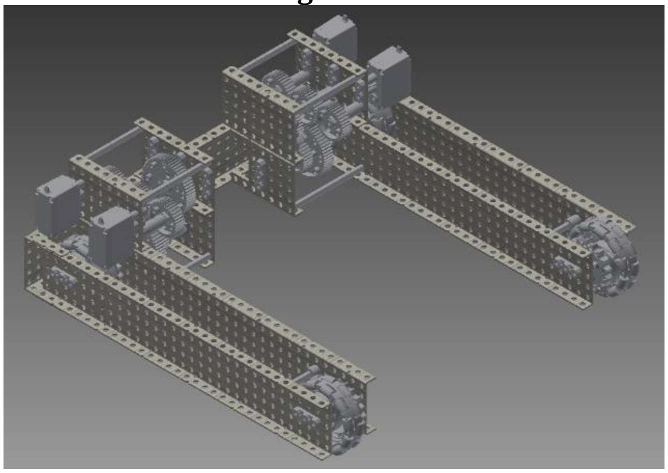


Figure 57



4.1.2 X-Drive

We had a big discussion on if we wanted to have an X-Drive because there are good benefits that come with it. There are some bad issues that come with it, which is why we decided not to pursue this. An X-Drive is a good drivetrain because it can not only go forward and backward, it can also go side to side. This can be helpful when maneuvering around the field, as seen in **Figure 58 and 59**. It also would make it easy to aim a shooter because the turning ability of the X-Drive is better compared to the Tank Drive. A bad issue about the X-Drive is that the pushing power is less than a tank drive because the wheels are on an angle, but it goes just as fast as forward and backwards and side to side. Another issue is that it also takes up lots of space, which makes it hard to build around it and incorporate the other subsystems.

Figure 58

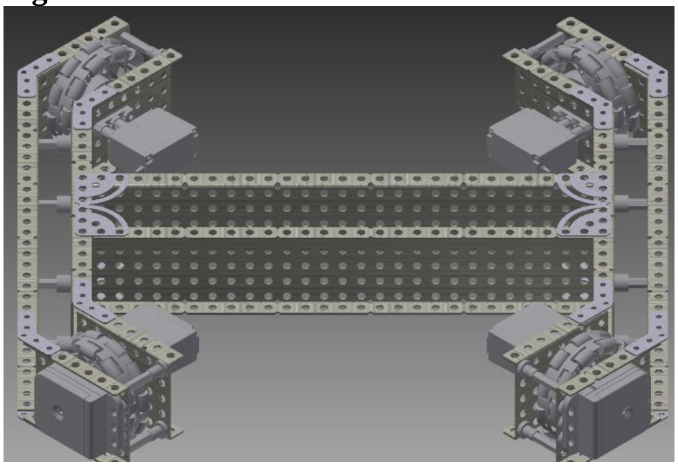
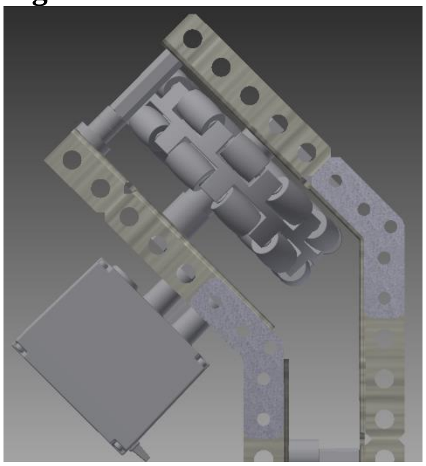


Figure 59



4.2.0 Collector

4.2.1 Double Ball Collector

We thought that since there are so many balls on the field that we should be able to collect them as fast as we can. That is why we thought about a double ball collector. This especially would come in handy for the pyramid of balls around the field, as seen in **Figure 60**. All we would have to do is drive straight into them, and we would be able to collect all of them. The problem with this design is that it was hard to figure out how to funnel the balls into the shooter, as seen in **Figure 61**. We wanted to use pneumatics for some of the other subsystems, but we only had 10 motors, and we only had two for the collector and feeder. The only way we could funnel the balls is passively by gravity but the balls don't move when they are touching each other, so this design was not possible.

Figure 60

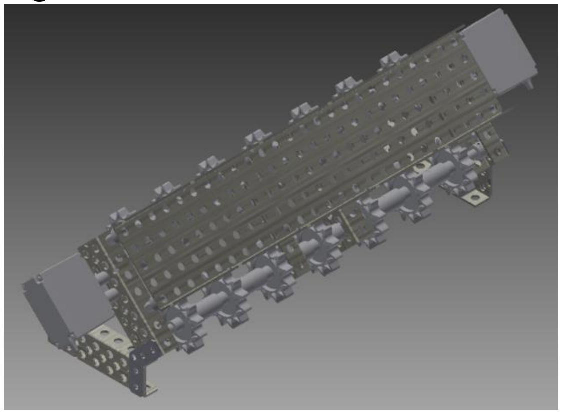
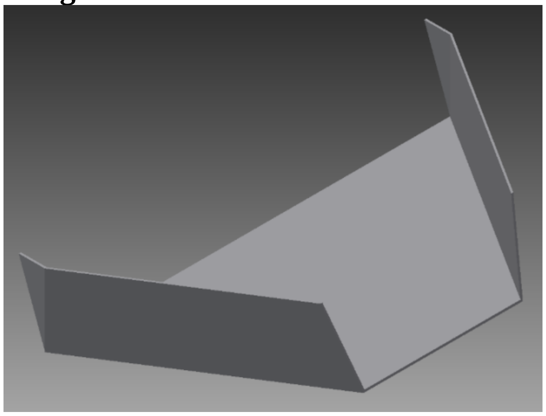


Figure 61

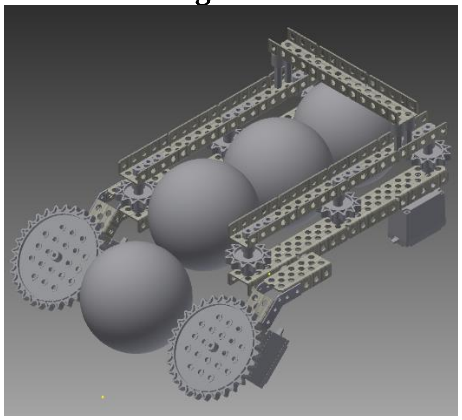


4.3.0 Feeder

4.3.1 Long Ball Conveyor

This design would have been likely used if we decided to go with the fly wheel design. Instead of having the conveyor on the top or bottom of the ball, it would be on the sides because it makes it easier to feed the balls into the shooter. The problem with this design is that it's really hard to store all four balls in the robot, as seen in **Figure 62**. It also makes it hard to figure out how to human load balls into the robot. This design is also hard to mount on the robot and getting the balls to transition well would be even harder.

Figure 62

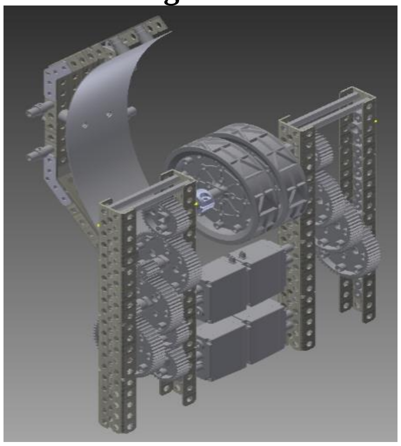


4.4.0 Shooter

4.4.1 Fly Wheel Shooter

When designing the shooter, we really only had two designs the fly wheel and the 4 wheel shooter. It was hard to decide which shooter was better, but the fly wheel shooter had a little more disadvantages than advantages. The fly wheel took up a lot more vertical space, or space in the middle of the robot, as seen in **Figure 63**. It also required the wheel to shoot at a faster speed because of the friction of the plate. This required a higher gearing which would take up more space. Also, getting the pinch right on the ball is hard, and keeping the shooter in good condition requires more time and effort than a 4 wheel shooter.

Figure 63



5.0 Detailed Design Description

5.1.0 Drivetrain

5.1.1 Aluminum Frame
5.1.2 4 High Speed 393 Motors
5.1.3 U – Shaped Chassis
5.1.4 4 3.25” Omni Wheels
5.1.5 Sprocket and Chain Drive
5.1.6 2 Gearbox to Tie Motors
5.1.7 2 Encoders
5.1.8 2 Pneumatic Piston Stoppers

5.2.0 Collector and Loading Basket

5.2.1 Tank Treads Collection Material
5.2.2 45 Degree Collection Angle
5.2.3 1 Turbo Speed 393 Motor
5.2.4 Aluminum Basket Frame
5.2.5 45 Degree Basket Angle

5.3.0 Feeder

5.3.1 Tank Treads Collection Material
5.3.2 1 Turbo Speed Motor

5.3.3 Polycarbonate Guides
5.3.4 3 Limit Switches

5.4.0 Shooter

5.4.1 High Strength Wheel Shafts
5.4.2 4 84 Tooth Gear with 4” Tear
5.4.3 4 Regular 393 Motors
5.4.4 25:1 Gear Ratio
5.4.5 45 Degree Shooting Angle
5.4.6 2 Pneumatic Piston Deflector
5.4.7 2 Encoders

6.0 Team 33A “Hotshot” VEX Robot Software

6.1 Description

The software running on Hotshot has been created with the goal of enabling the machine to score as many points as possible. In my team’s history of creating software for various robots, we have often found that the robots that require the least amount of human input to complete the assigned task are the quickest at scoring the most points. So, falling in line with this theme, we decided to automate our storage and indexing of balls as well as the shooting process. This leaves the driver with the tasks of driving the robot, collecting, and selecting what speed he would like the shooter to go to depending on where he wants to score on the field. Hotshot itself is composed of 4 subsystems: the drivetrain, the collector, the conveyor/magazine, and the shooter. The software behind each individual subsystem is covered in depth below.

6.2 Drivetrain

Hotshot’s drivetrain is a four wheel drive with two omni wheels on each side. The sensors that provide feedback for this subsystem are the encoders on the left and right side of the drivetrain and the gyroscope that sits in the center of the robot. In autonomous, these devices enable the robot to complete its navigation routines to get to balls that are not a part of our pre-loads. This year, our team is trying something new where we use motion profiles to achieve our turning and driving targets instead of generic PID. By generating a motion profile and using FeedForward terms alongside PID feedback, we have found that we create autonomous routines quicker than with generic PID and with greater accuracy. The motion profile itself is simply a function that takes inputs of desired position, speed, and acceleration and generates outputs of where the robot should be and what speed it should be going at every timestep that the code is executed (for us this is once every 25 milliseconds or 40hz). This was achieved through the use of 1 dimensional kinematics and the profiles generated are either trapezoidal or triangular depending on the parameters entered. Once the outputs have been generated, a follower is used to produce values that the motors should be moving at. The follower is a FeedForward control scheme combined with a PID feedback loop.

For teleop, the driving interface is a more developed version of the standard arcade drive known in FIRST robotics as the Cheesy Drive. Through the use of a few tunable constants, the robot's responsiveness to turning input can be heightened or dampened depending on what the driver feels comfortable with. This is useful not only for general driving actions but also for lining up with the goal from long distances. If the shooter is running, the drivetrain can automatically dampen its response to user input for turning so that the driver can more easily take caution in correcting for any misalignments when trying to shoot across the field. The encoders and gyro are used in teleoperated play for feedback in a feature called dynamic braking. This allows the driver to hold a button and lock the current position of the robot via a feedback loop using the encoders and gyro. Through this feedback loop, the robot will actively correct its position to prevent from being pushed around by other robots.

6.3 Collector

Hotshot's collector requires very little logic from the software side of things. The action of collecting and blowing out game objects is controlled via two buttons on the driver controller. There are no sensors in this subsystem.

6.4 Conveyor/Magazine

Hotshot's conveyor is where balls that have been collected are either stored until we are ready to score or conveyed into the shooter. The primary objective of the software running this subsystem is to determine when to activate the conveyor to hold more balls as well as when to change its logic to take commands from the shooter rather than its own sensor inputs. To achieve this objective, limit switches are used at the base of the conveyor, halfway up the conveyor, and at the top of the conveyor. Using the feedback from these sensors and establishing logic to handle all of the different combinations of inputs that can be received, the conveyor is either turned on at full power or commanded to remain idle.

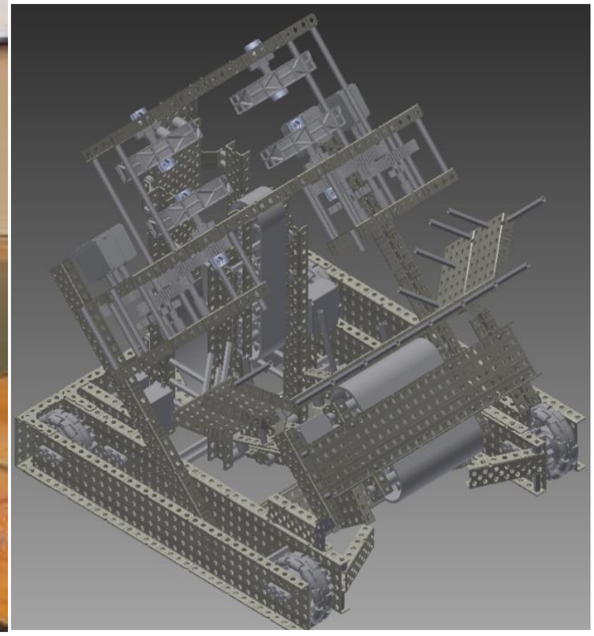
6.5 Shooter

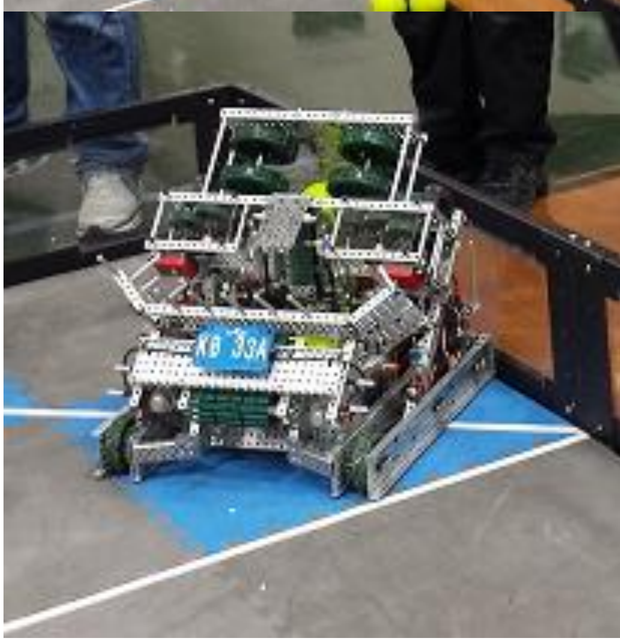
Hotshot's shooter is the robot's primary scoring mechanism. The goal of the software on this subsystem is to allow the robot to score as many game pieces as possible within the shortest time as accurately as possible. To achieve this objective, encoders are used on both sides of the shooter to monitor the RPM of the shooter wheels. This RPM is fed as a process variable to the velocity PID loop that actively controls the output to the shooter motors. Running concurrently with this velocity feedback is velocity feedforward control that takes its commands from a velocity profile generator that tries to estimate the approximate speed the shooter should be running at based on the target velocity and maximum acceleration the shooter can handle. Through the use of this combined velocity feedforward and velocity feedback system, tuning the feedback loop is fairly simple and the stability of the system is beyond satisfactory. In brief, the process for shooting is as so, the user selects a desired shooter speed (in RPM), the system takes this target speed and maximum acceleration indicated and generates a profile that feeds an estimate of what the velocity should be to the feedforward loop while the feedback loop cleans up whatever the feedforward loop could not accomplish.

The system described above really accounts for how quickly Hotshot can unload its magazine. Every time a ball is shot and the energy transfer slows down the shooter, the velocity feedback loop will ramp up the motors by a fairly accurate amount (using proportional and integral terms). Once the correct speed is reached, this allows for the automation defined on the Conveyor/Magazine subsystem to send more game pieces through the shooter.

7.0 Final Robot Pictures

These are pictures of the final Killer Bee Team 33A VEX Robot.

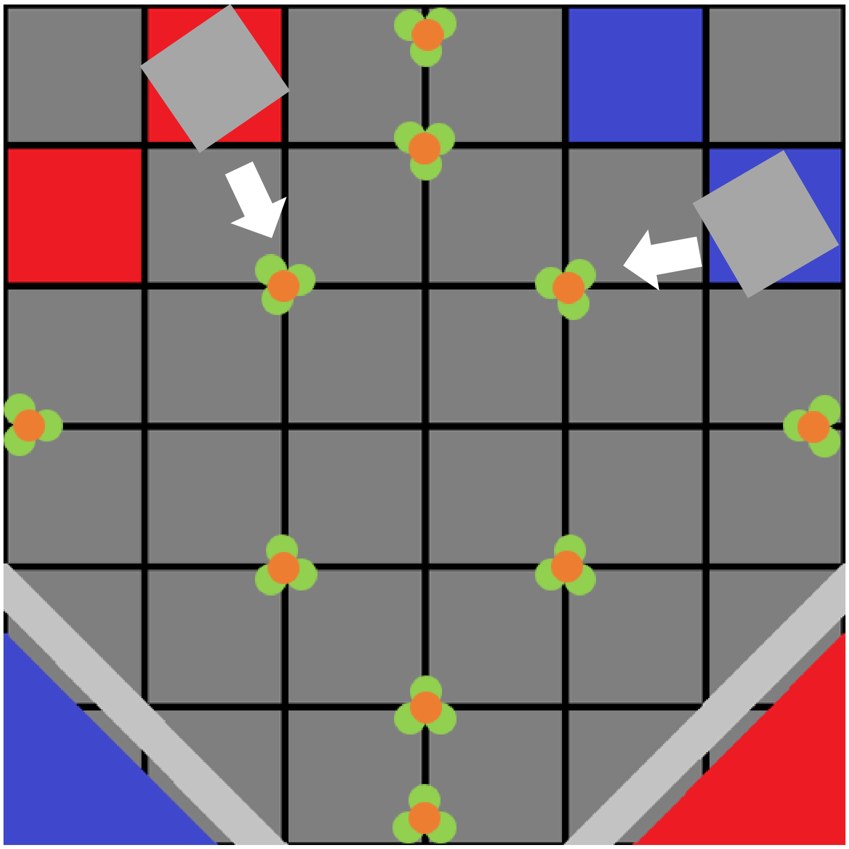




8.0 Extras

8.1 Auton

Like many VEX teams, their robots shoot 4 balls from their starting tiles. We also shoot 4 balls from the starting tiles; however we also have more autons than that. We have an auton that drives up to one of the group of balls and then shoots the 4 preloads. The robot then, hopefully, collects a normal ball and the bonus balls and shoots them in the goal for more points. This ultimately gives us the auton win and the lead in the match or make up for any preloads missed.



8.2 Strategy

There is always a strategy that an alliance can make to win the match. The best way to win a match is to win auton, and then score as many bonus balls as possible and then the rest of the balls on the field. After most of the balls are off the field, then one robot gets the rest of the preloads and shoots them, while the other robot plays defense if the other alliance is trying to elevate. The best robot to choose is a robot that can pick up off the floor.

8.3 Scouting

Every year our team makes a scouting sheet for each game; this makes it easier to select teams during the alliance selection.

Team # ___________ Team Name ____________________________________

Match	Auton			Teleop				Other Rating (1 – 6)						Other
#	HG Shoots Made	LG Shoots Made	Missed Shoots	HG Shoots Made	LG Shoots Made	Bonus Balls Made	Shoots Missed	Driving	Defense	Accuracy	Collection	Shooting Speed	Human Player	Main Shooting Area

Comments:

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8.4 Competition Overview

8.4.1 BeeMo' Tournament

After Qualifications, we were in first place with a record of 6-0-0 and a SP score of 366, and an OPR of 130.49. We selected 35A Cranbrook and 2337D EngiNERDS. We got all the way to Finals and lost, but were Tournament Finalists and won Robot Skills and the Excellence Award.

8.4.2 Mid-Michigan VRC Qualifier in Haslett

This was another good tournament. We went undefeated in the qualification matches and were in second place. We had a record of 6-0-0, a SP score of 249, and an OPR of 173.38. We were selected by the first placed team, Team 5801 Robo Storm, and went undefeated in eliminations and were one point away from 300. We were the Tournament Champions and Robot Programming Skills winner.

8.4.3 Notre Dame Preparatory Vex Competition – HS Only

This was our best tournament yet and once again we went undefeated in the qualification matches. After qualifications, we were in second place with a record of 6-0-0 and a SP score of 139, and an OPR ranking of 166.11. We were selected by the first placed team, Team 1684B, The Chimeras, and went undefeated in the eliminations matches and got the highest score in Michigan with a score of 321. We were Tournament Champions, won Robot Skills, Robot Programming Skills, and the Excellence Award.

8.4.4 Michigan State Vex Championship – HS Only

This was a very comptetitive tournament, but we did very well against the competition. We went undeafeted in the qualification matches. After qualifications, we were in second place with a record of 6-0-0, a SP score of 714, and an OPR of 144.92. We weren't selected by the first place team, so we became the second alliance. We selected team 35 Terminal Velocity, and team 4911A High Voltage. We got all the way through to the finals and lost to the first alliance teams in the finals. We were Tournament Finalists and qualified for the Vex World Championship in Louisville, Kentucky.

9.0 Achievements

Excellence Award	BeeMO' VEX Tournament, October 17, 2015
Robot Skills Winner Award	BeeMO' VEX Tournament, October 17, 2015
Tournament Finalist Award	BeeMO' VEX Tournament, October 17, 2015
Tournament Champions Award	Mid-Michigan VRC Qualifier in Haslett, December 12, 2015
Programming Skills Winner Award	Mid-Michigan VRC Qualifier in Haslett, December 12, 2015
Excellence Award	Notre Dame Preparatory Vex Competition – HS Only, December 19,2015
Tournament Champions Award	Notre Dame Preparatory Vex Competition – HS Only, December 19,2015
Programming Skills Winner Award	Notre Dame Preparatory Vex Competition – HS Only, December 19,2015
Robot Skills Winner	Notre Dame Preparatory Vex Competition – HS Only, December 19,2015
Tournament Finalist Award	Michigan State VEX Championship Touranment, February 22, 2016
VEX Worlds Qualification Award	Michigan State VEX Championship Tournament, Feruary 22, 2016