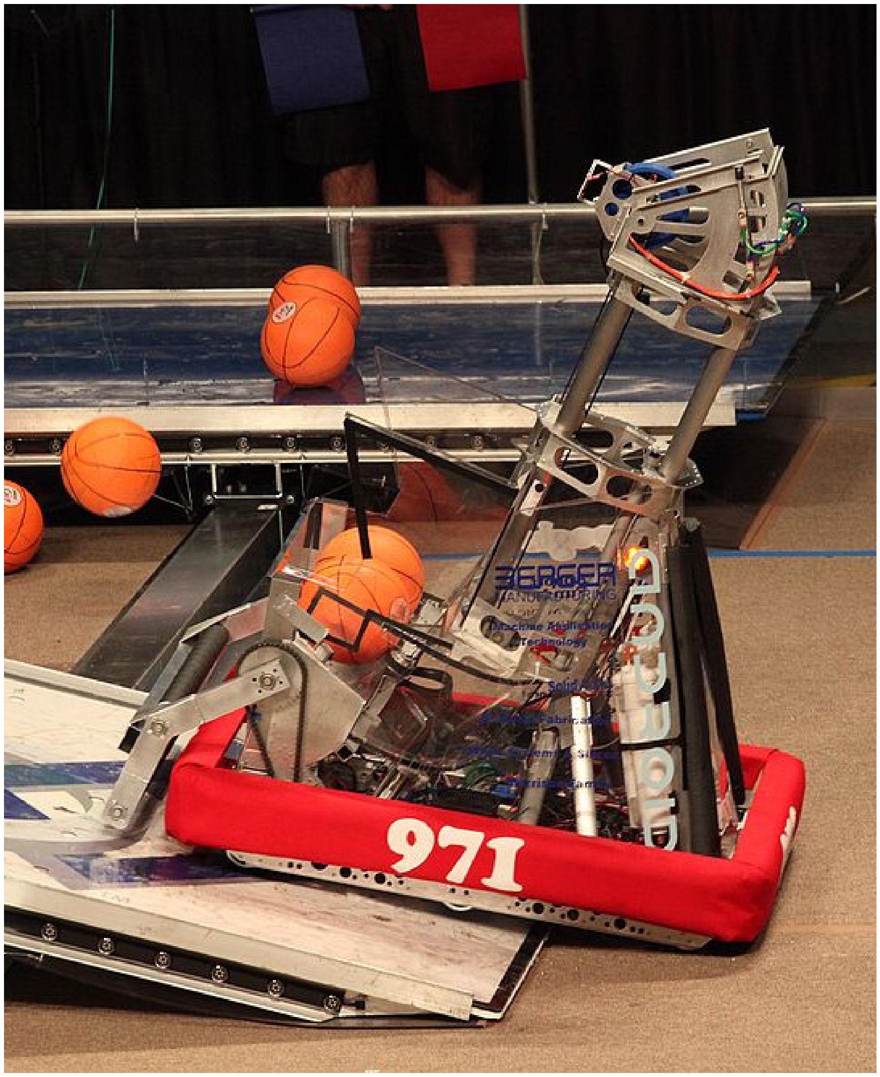
Spartan Robotics
FIRST Team 971

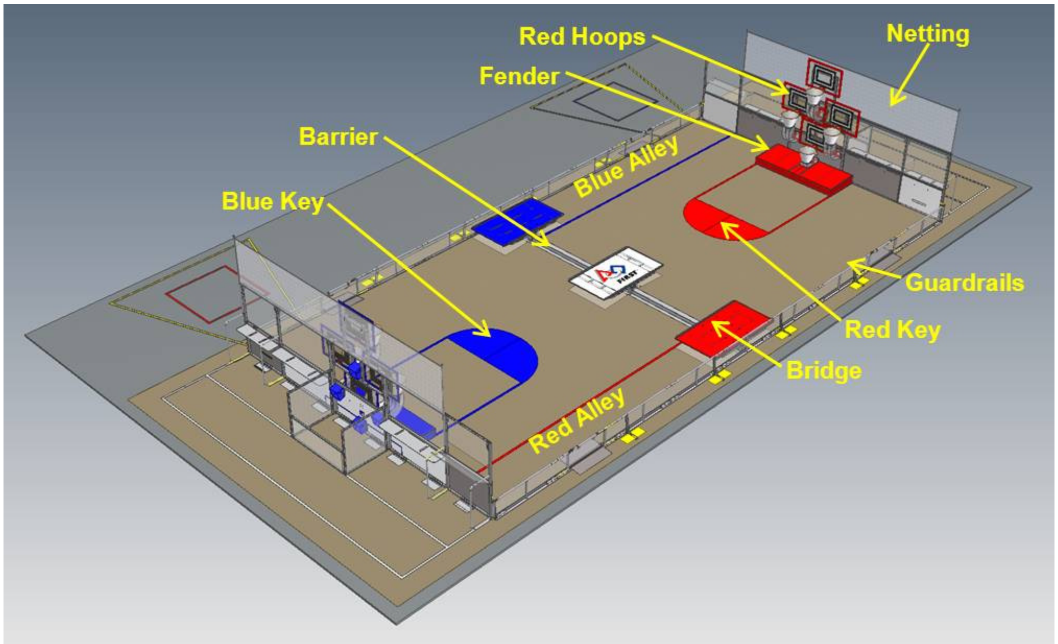


Renegade

Technical Documentation
2012

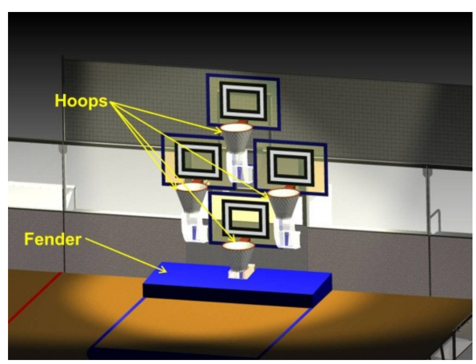
The Game

The first thing any of us do for Build Season is have a great understanding of the rules and game and establish what kind of robot we want to build. This year, the game, Rebound Rumble, presented all sorts of interesting challenges to solve.



The game as always is played on a 27x54 foot field, but this year there is a 4x6 inch steel barrier that divides the field in half. Also, bridges dominate the center, providing obstructions but also opportunities for a significant amount of points in the endgame. The hoops that the robot has to score on have 3 levels, with an increasing number of points the higher the hoop. About 12 feet away from the hoops is a protected zone called the key.

Strategy Goals



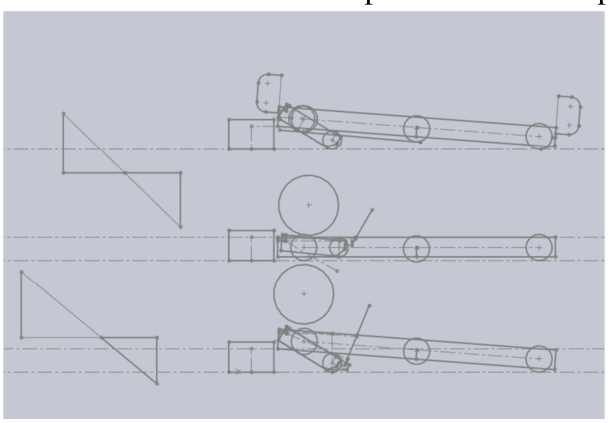
We decided we wanted to shoot from both the fender and the key to maximize our scoring ability. We also decided that we wanted to focus on the top hoop for the most points, but with the requirement that we make at minimum 67% of our shots to create a net benefit from shooting there as opposed to making 100% of shots in the middle hoop, at a much lower height and an easier shot to make. We also recognized the need to have an effective drivetrain to control the pace of the game and help balancing on the bridge.

Drivebase
When analyzing this year's game, we realized that a fast and controllable drivebase was critical to do well and score a high volume of baskets. We realized that to maximize the amount of time scoring, less time was available for transportation purposes. With that is mind, we looked to our drivetrain first for designing.

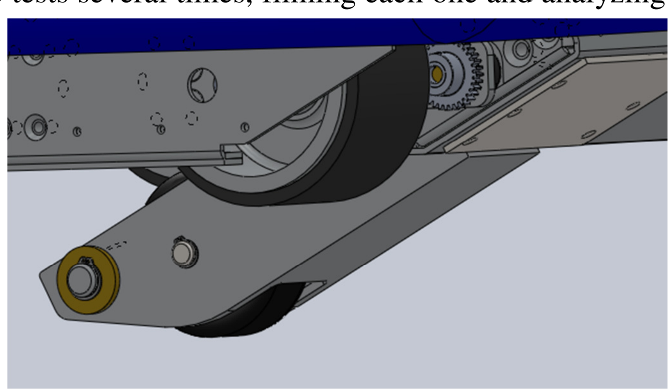
Two aspects of this year's game stood out to us as additional areas of focus apart from the normal drive aspects that we normally try to incorporate (speed, control, and pushing ability). These aspects were created by the steel barrier in the middle of the field and the bridges the robot balances on in the endgame.

Skids

The barrier was a difficult problem that we spent a lot of early resources on. We needed to find a way to get over the barrier quickly and efficiently to not lose speed on the way across the field.



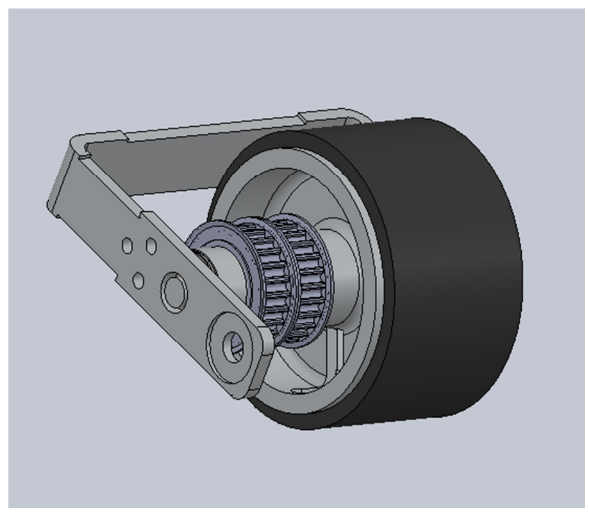
We started by having multiple ideas thrown out and modeled to see if the geometry would work in respect to the barrier. Many of the ideas considered that were initially rejected as impractical were additional wheels and certain passive mechanisms to vault the robot over, since the mechanisms were often requiring additional complexity to get a smooth geometry to work. Progressing on with the ideas that appeared to be the most promising in working with the geometry, we built scale prototypes to model the effect of several ideas, mostly relating to either raising the level of the robot or having angled skids to force the robot at a specific angle and allow it to drive over the bump. We ran multiple tests several times, filming each one and analyzing the video afterwards to look at how the design behaved. After those tests, we felt fairly comfortable with the idea of active drop down skids to get the robot over the barrier. To confirm that this idea would work, we attached a concept mechanism to a previous year's drivebase and drove the robot over the barrier without issue.



Confident that this idea would work, we then proceeded to model the mechanism in CAD, first determining the correct angle that was appropriate for the skids. We determined that the angle needed to be sharp enough to get the robot up quickly but not higher than necessary since the more energy that is translated into the robot going up results in less energy that can be used to move the robot forward. In addition, the geometry was also limited by the bumper rules, which we carefully planned around. We could not have the bumpers go above the 10" limit when the skids were deployed, giving us a small window to work with. The angle ended up being approximately 30 degrees.

Wheels

One of the other aspects of this game was the slippery bridge in the endgame and the general rules of the game that lends itself to a high amount of robot to robot interaction, especially at the high levels of regional and championship play. Due to this, we decided that it was going to be very important to have a high amount of traction and pushing ability in order to have no issues driving and getting to where we want the robot to go.



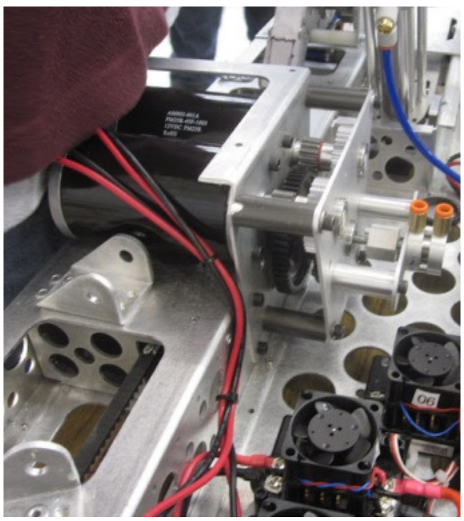
In order to increase our traction and increase our pushing ability (and resistance to being pushed ourselves by other robots) we decided to go with 2 inch wide wheels instead of the traditional 1 inch wide wheels that most teams go with. This means more surface area touching the carpet, thus more traction.

The other part of our innovative wheels is the fact that it makes tread changes very simple. The tread is attached via a zip tie and is cinched down in a gap in a simple way to make it easier to put on and take off the tread.

Speed and Efficiency

Additionally, the wheels are only 3.5 inches in diameter instead of the standard 4 inches. This allows us to get down to our desired gear ratio with less gear reductions, increasing efficiency. After every gear reduction, the power transferred to the next stage is only about 90-95% of the previous stage, so reducing the amount of reductions makes a significant difference since we try and get the maximum performance out of our drivetrain. Our gearing takes advantage of a 60 tooth and 45 tooth dog gear to achieve that reduction and also allows us to space the CIM motors far enough apart so that they can fit over the drivetrain and out of the way of the electronics panel.

We also gear for around 16 feet per second (fps) in the highest gear speed (we have a 2 speed transmission) for a few different reasons. One is that it is a ratio that we have used for several years now and have not had any problems with it; in fact we often have one of the fastest robots in the nation. Second, we have run calculations that even in a dead sprint, due to the limitations with the size of the playing field and the time it takes to accelerate, 16 fps is the fastest a robot would need to go. Third, once the robot gets much higher than 16 fps it becomes very difficult to control and often has trouble accelerating. Often a driver needs this acceleration to speed around a defending robot.

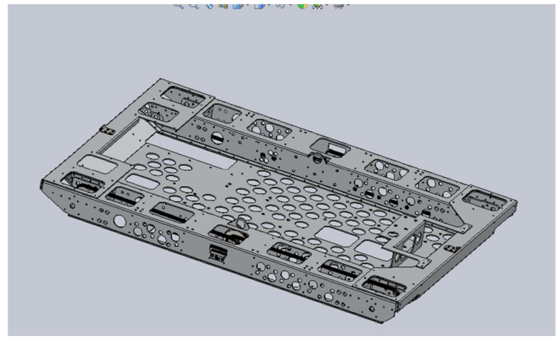


In the power aspect of the robot, we decided as we have for most years now (with the exception of traction limited 2009) to have 4 CIMs in our drivebase, an automatic design decision. CIMs are the most powerful motors and the only motors that are completely sealed, meaning they do not need to be spinning and have airflow to cool down. This choice allows us to have the power needed to go at the speeds we want and have the pushing power we want.

Driving the wheels is a timing belt, not chain, a change we made just this year. Belts hold several advantages. One, they are more efficient, since they can bend much easier and have less friction than chain, which has individual metal links instead of a flexible polymer and Kevlar. Second, Kevlar timing belt (the type we use) does not stretch, so requires very little upkeep to tension. Third, it is quieter and cleaner than chain, which is metal and greasy. Timing belt is also overall lighter than chain.

We decided to go with a narrow orientation drivebase because of the stability and control it affords us as well as our good experience controlling narrow drives. We felt that the driving ability of a narrow drivebase outweighed the benefits of going wide: increased intake space and space on the bridge for balancing. This was because of our work on innovative intake ideas and our driving ability and stability on the bridge.

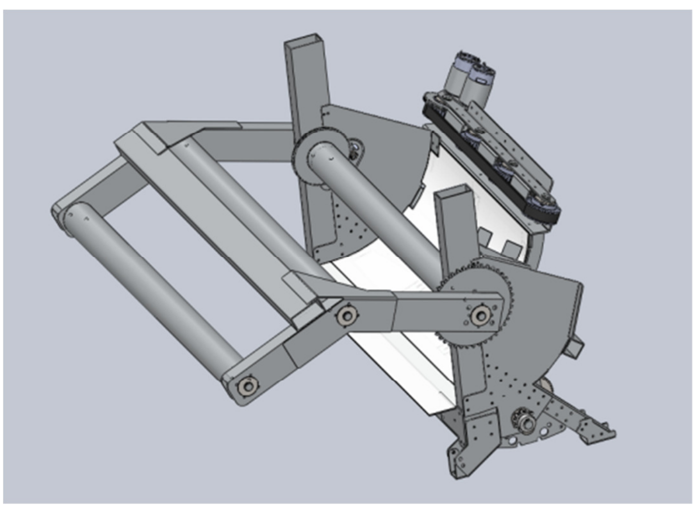
Structure



The overall structure of the drivebase is a feat of engineering in of itself. The main part of the drivebase is made up of only 3 sheetmetal 0.090" thick pieces that as total weigh less than 12 lbs. There are many other smaller pieces but the vast majority of the frame is made out of punchable sheet metal pieces, allowing our manufacturer to more efficiently make the parts (the gearboxes are the notable exception, since they need to have laser cut tolerances to work). The whole base is put together rather quickly with rivets, making it simple and quick to assemble.

Intake

The Intake was our next focus of the design. When we looked at the game, we realized that taking a large amount of balls very quickly was critical for succeeding. The less time spent collecting balls means the more time available for shooting.

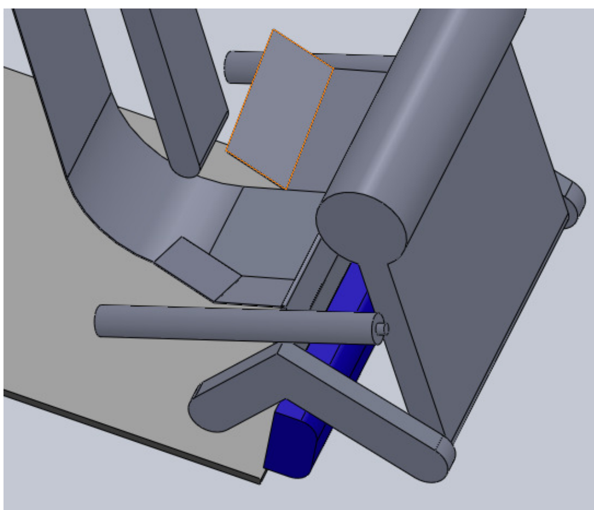


Part of the challenge of this design aspect was the bumper rules. The robot is required to have at least 8 inches of bumper coverage from each vertex, so intake space is severely limited, giving only about 12 inches for a narrow drive and 22 for a wide drive. We felt that this was not optimal given that we were favoring a narrow drive and the balls were about 8 inches in diameter (7.9" based on the average circumference provided by the manufacturer.) Given this, we worked on developing an over the bumper intake system so that we could maximize intake size. By collecting over the bumper, we could also move the balls vertically above the frame quickly to not take up space for the electronics panel and wouldn't require adaptations to the frame, which would potentially make it weaker, a negative aspect considering the robot goes over the central barrier with a considerable amount of force.

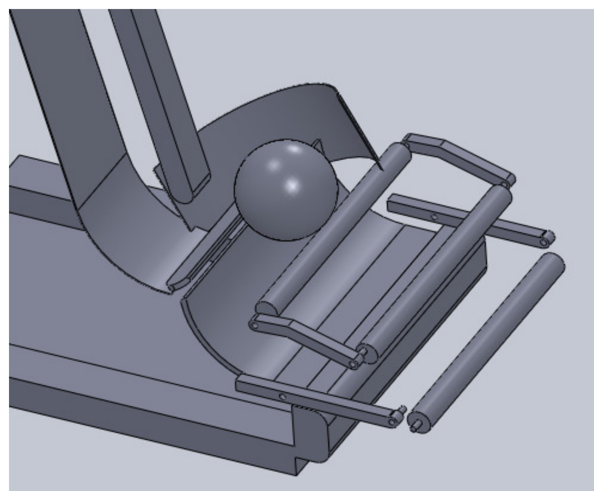
For the intake, we attempted to design without using polycord. Having used it in 2009, we experienced multiple problems with belts stretching and getting loose. Additionally, polycord requires a lot of machining resources to make the rollers with grooves, something that would be challenging for our team. We combated this problem with having 3 rollers spaced apart with enough compression to get the ball over. We built a prototype and tested it hundreds of times, often making small adjustments and then translating those measurements directly to the geometry in the CAD.

Ball funneling

A larger problem about our over the bumper intake was the funneling and serializing of balls into the shooting column to get the balls ready to shoot. We came up with multiple concept ideas, 8 in all, and did many tests to prove concepts before settling on one idea that we were satisfied with testing more. This idea involved a horizontal roller to move the balls all to one side and around a corner so they would not be jammed together coming into the shooter.



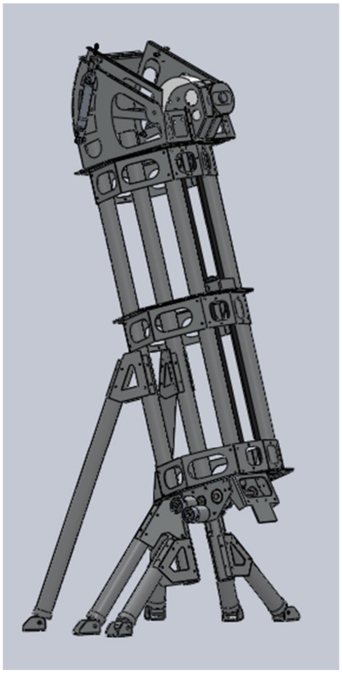
Alternative Design Concept



One of 8 concept designs

We then proceeded to run many tests and hundreds of trials in order to get the intake to work with multiple balls coming in without the intake getting jammed, preventing the flow on balls into the shooter. We often used 5-6 balls at once to accentuate the problem instead of the normal 3 to try and get the mechanism jammed in an attempt to find areas of weakness in the design. We made modifications after each test and based the geometry of the design after our prototype that did not get jammed at all after several trials with several balls inserted at irregular and fast intervals.

Superstructure



The other main structure to our robot is our superstructure, which holds up our shooter and holds balls after they have been taken into the robot. We determined through our shooter tests that we wanted to achieve approximately a 27 degree angle at around 55 inches, a height well suited to have a good angle towards the top hoop and shoot over potential defense. Given that height, we needed this structure to be very light, but also rigid to provide a solid base for the shooter, since we found that the variability in shots was increased dramatically by the vibrations and flexing in the shooter structure.

Given these requirements and our research into what has been done before in these areas, we settled on round tubestock that was 1/32" thick and 1.5" diameter. This tubestock, used in the past by team 67 (HOT), is extremely light but also very rigid in structure because it is circular tube (as opposed to the traditional square or rectangular tube that can flex more under pressure because it doesn't distribute the force evenly) making it a great investment for the weight vs. strength.

The whole superstructure is attached together with sheet metal brackets, secured with rivets and high strength aluminum glue. The superstructure is attached to the rest of the robot with only 6 bolts so it can be easily removed and switched out with a replacement if needed. Also, the support brackets come down at angles as to not obstruct the electronics panel, allowing a large access area to service the robot.

Shooter

For the shooter, we looked for something simple and effective to achieve what we wanted to do. From our strategy discussions, we realized that both shooting from the key and the fender was something that was very important, and we kept that versatility in mind when designing the shooter.

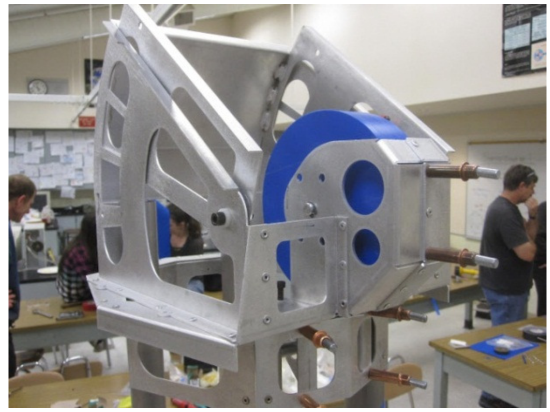
We studied shooter designs from 2006, a similar game to 2012, specifically looking at teams like 254/968 design (Cheesy Poofs/RAWC), and shooters from 2009, like 1114 (Simbotics) and

Optimal angle consistansy test

Shot #	Distance from hoops in inches	Hoop Scored?	V. Angle of Shooter in Degrees	H. Angle of Shooter in Degrees
6	55	Yes	27	0
7	55	Yes	27	0
8	55	Yes	27	0
9	55	Yes	27	0
10	55	Yes	27	0
11	144	Yes	27	0
12	144	Yes	27	0
13	144	Yes	27	0
14	144	Yes	27	0
15	144	No	27	0
16	144	No	27	0
17	144	No	27	0
18	144	No	27	0
19	144	No	27	0

Excerpt of Shooter test Data

217 (Thunderchickens). From this, one of the first decisions we had to make was whether or not we wanted a turreted shooter or not. Based on our work and machining resources and other complicated aspects of our robot, we decided to simplify the design and have a static shooter. Next, we had to test what kinds of variability we needed for shooting from the key and from the fender.



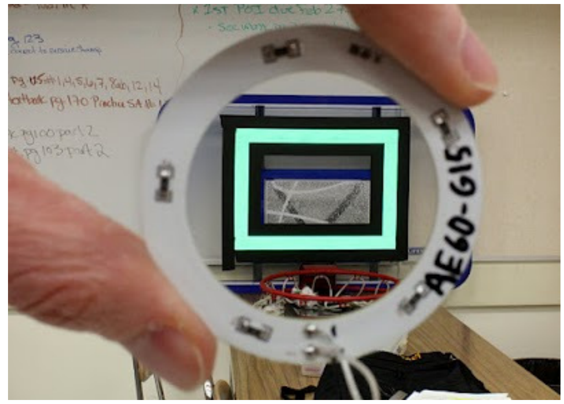
To test this, we designed and quickly built a sheet metal prototype shooter to test the relation of shooter hood angle and speed of the shooter wheel to achieve different lengths and heights of shots. We found that we could achieve a large degree of variability with an angle of 27-30 degrees from vertical and varying the rpm of the motor.

Ball Storage

We elected to have a very small hopper this year for the reason of it's not being used to store a large amount of balls, given that the robot can only hold 3 balls at a time. Additionally, we designed the hopper to be able to load from the human player slot if necessary, but the main function of the hopper is to keep the balls contained so they can bounce around and sort out before being sucked up into the vertical column, which is our primary storage of balls. The vertical column is powered by a vertical conveyor that can move the balls up and down to feed individual balls to the shooter.

Sensors

We have multiple sensors all over our robot to increase the accuracy of the mechanical actuation and increase automation. On the drivebase, we have encoders to count the revolutions of the wheels. This information allows us to create control loops for driving that allows us to drive smoothly and efficiently with a greater amount of speed and control than the vast majority of teams in FIRST. Also on the drivebase, we have a specially designed gyroscope circuit board that takes data from a gyroscope (among other sensors we can attach to this custom circuit) and use this in driving, especially during autonomous. On the intake, there is an encoder to track at which angle the intake structure is at as well as enabling us to write control loops to increase the speed of the intake coming up and down and ensuring the intake is at the right spot, a very critical feature since a difference of an inch or more in the position of the intake could prevent us from effectively controlling a ball upon contact. The intake also has a Hall Effect sensor to index the encoder. We elected not to use an actual limit switch since we had trouble with limit switches misfiring and not being robust enough last year with regards to indexing our elevator. Once the ball is controlled by the intake, two IR photoswitch sensors control the spacing of the ball in preparation for shooting. The first one senses that a ball is in the robot and runs the vertical conveyer to get the ball stored in the vertical column below the shooter. The ball will then travel up, but does not travel past the second sensor which stops the balls short of the shooter wheel so the wheel has time to run up to speed. The shooter wheel's speed is measured by a gear tooth sensor, which allows us to vary the length and arc of our shots. Finally, we have a camera to locate and target the hoops, enabling us to have more accurate shots. We use a Logitech C210 webcam for our camera and use two bright green LED light rings for reflecting light off of the retro-reflective tape on the backboards.



Control Methods

This year we went above the typical control system with the cRIO. We put a Fit PC, a small computer, running Debian Linux with a real time kernel on the robot which communicates with the cRIO through the wireless bridge. We minimized the amount of code that we have on the cRIO so that we do not have to worry about updating code on the cRIO, just on the Fit PC. Writing code for the Fit PC is also easier because we can use the much more extensive and well documented Linux APIs. This is the first time our team is using a secondary computing method.

Hybrid Control

After research into what the Kinect could do, we decided against using the Kinect for the primary use of control. With the amount of sensors we have and the degree of control we have over the robot, we found that the Kinect would be unnecessary as a primary use of driving our autonomous.

Driver Control

We have a 6 wheel drive that utilizes skid steering with a wheel and throttle, allowing the driver to have fine control over the robot and allowing the robot to spin and drive quickly in any direction. The separation of controls makes it easy to separate the action of steering from the action of throttle, increasing the accuracy of driving and ease of use. For the manipulator controls, we custom built an operator panel to allow the manipulator the fine control they need to quickly use automatic control and also have the ability to manually control everything; we can even disable all the control loops if the code is not working in a particular match.