Robot Design:
Patton

TEAM 708 HATTERS ROBOTICS

v1.0

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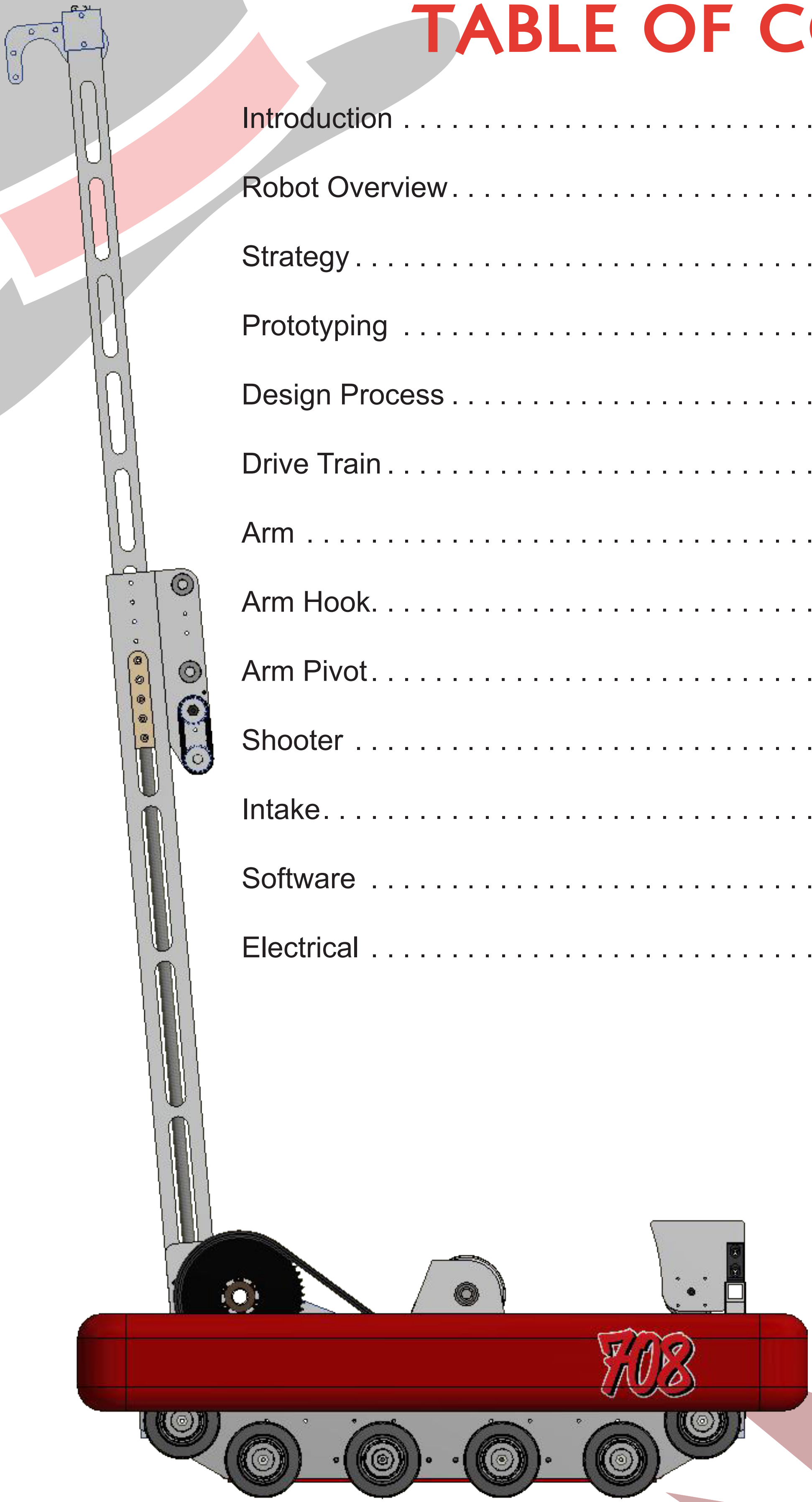
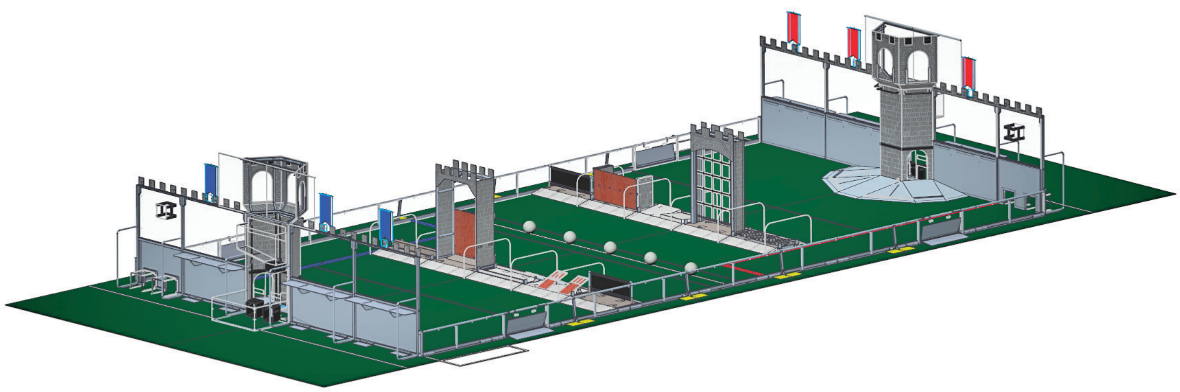
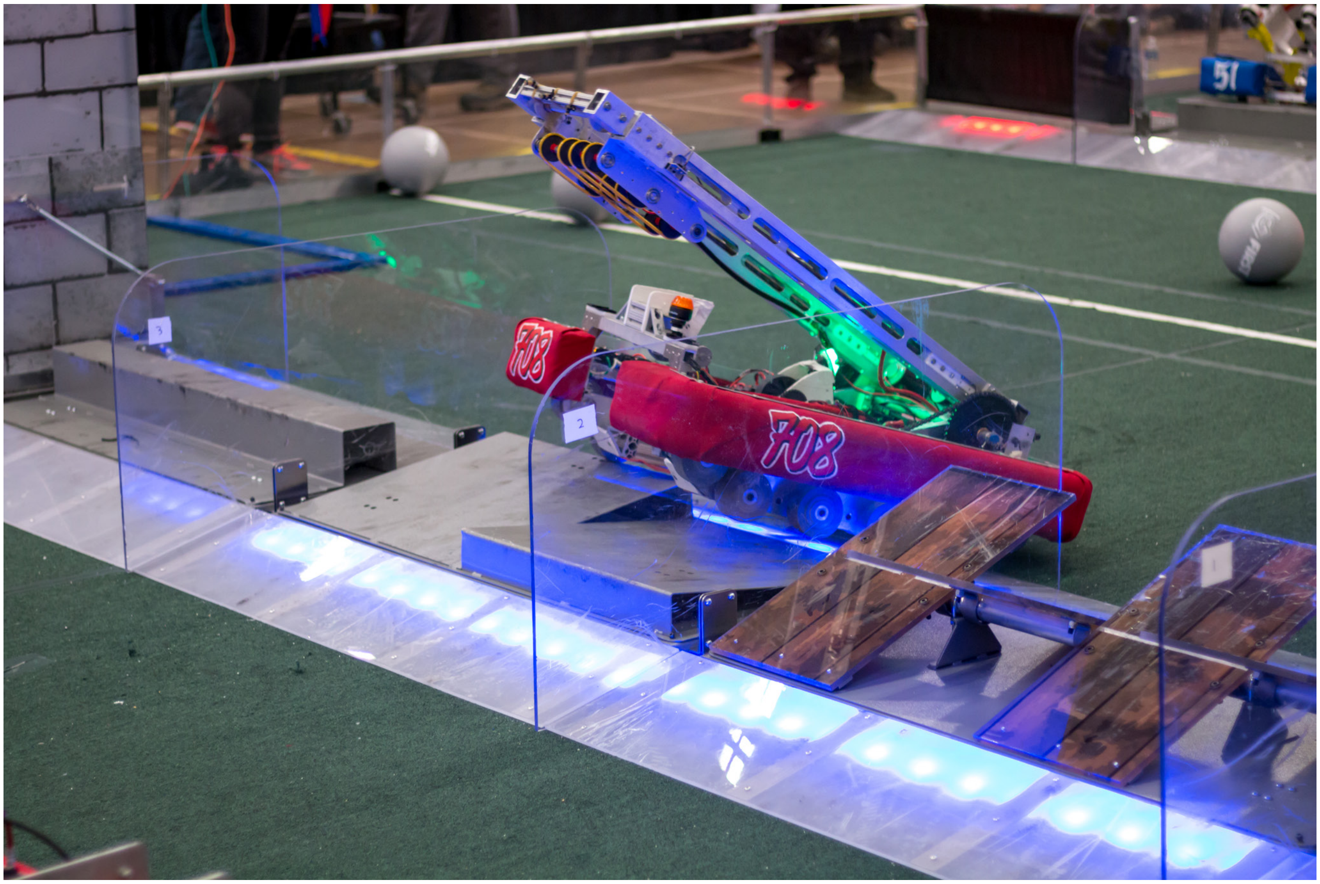


INTRODUCTION TO FIRST STRONGHOLD

The 2016 FIRST Stronghold game has many parts to it; robots must be able to drive over or manipulate several different obstacles, known as defenses, and cross over to the other side of the field. Then they need to shoot a 10 inch diameter ball (a boulder) in the opponent's' castle seven feet in the air, and aim through less than a foot and half tall goal. The Moat and Ramparts (class B), Rock Wall, and Rough Terrain (class D) are all accomplishable by making a proper drive train. The Drawbridge and Sally Port (Class C) are push and pull movements depending on which way you attempt to clear them. To round out the obstacles, the last components are the Portcullis and Cheval de Frise (Class A), which use up and down movements.



Another component to this year's game is the autonomous (auto) modes. The autonomous period is a 15 second section of the 2 minute 30 second match, where the robots have to maneuver completely on their own without human controls. Not only is there an Autonomous period but the rest of the match is the Teleoperated part of the match, where human player operate the robots.



In auto this year, robots can reach defenses to score 2 points, cross defenses to score 10 points, score in a low goal for 5 points, and score in the high goal for 10 points. In teleop passing through different defenses with the robot gives you a breach match points. After breaching four of the five defenses on the field, you get an additional ranking point. You also get a ranking point by capturing the tower at the end of a match. This game, unlike games before, has numerous ways to score points that are connected to completing other tasks on the field.

ROBOT OVERVIEW

Drivetrain

- 12 wheel drive with 1 inch 4 wheel drop center
- 4 in diameter by 2 in wide colson for maximum traction on diverse surfaces
- Custom 8:1 gearbox powered by 2 CIM gearboxes
- Capable of traversing class B and D defenses

Arm

- 775Pro powered arm pivot
- Custom 384:1 worm drive gearbox with additional 54:15 chain reduction for 1380:1 total reduction
- Capable of righting ourselves with the arm due to low center of gravity
- Lift powered by dual ½" ACME precision screws
- 8 start screw produces one linear inch per revolution
- 10.42:1 custom gearbox on 2 Mini-CIM motors
- Provides the ability to scale in approximately 5 seconds
- Wide hook catches bar for efficient hanging
- Spring loaded hook stays retracted to not interfere with low bar

Intake

- 775Pro powered Intake with 12:1 reduction versa planetary
- Mini Colson wheels with chain drive
- Single sided intake
- Can reverse to score balls into low goal

Shooter

- 775Pro powered single flywheel shooter
- 30:16 #25 chain reduction
- 9200rpm at the wheel
- Sure grip expanding flywheel
- 10:1 reduction BAG motor for feeder wheel
- Infrared sensor detects incoming ball and holds it in place for shooter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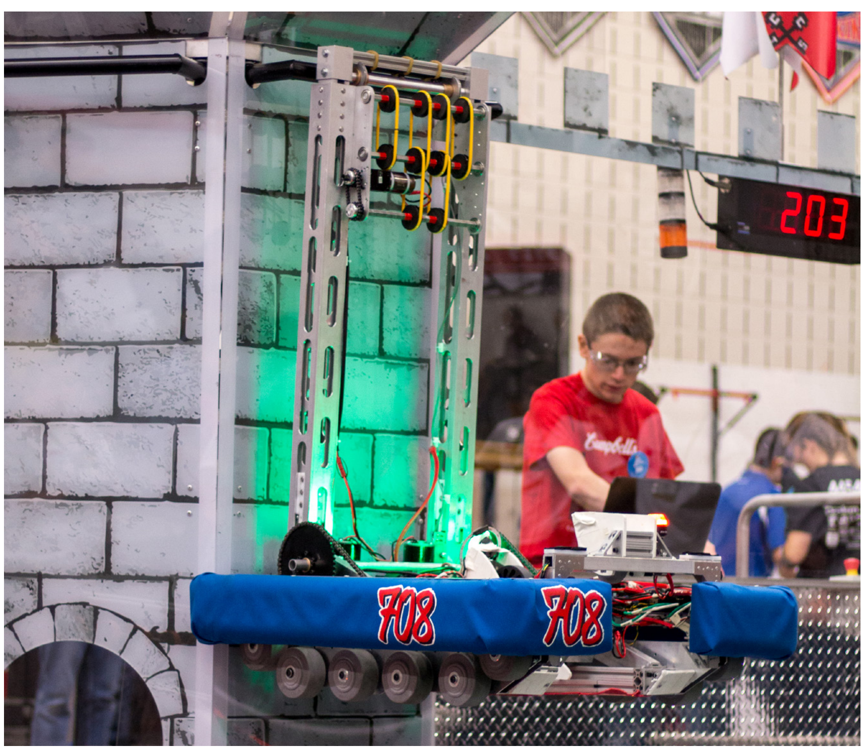
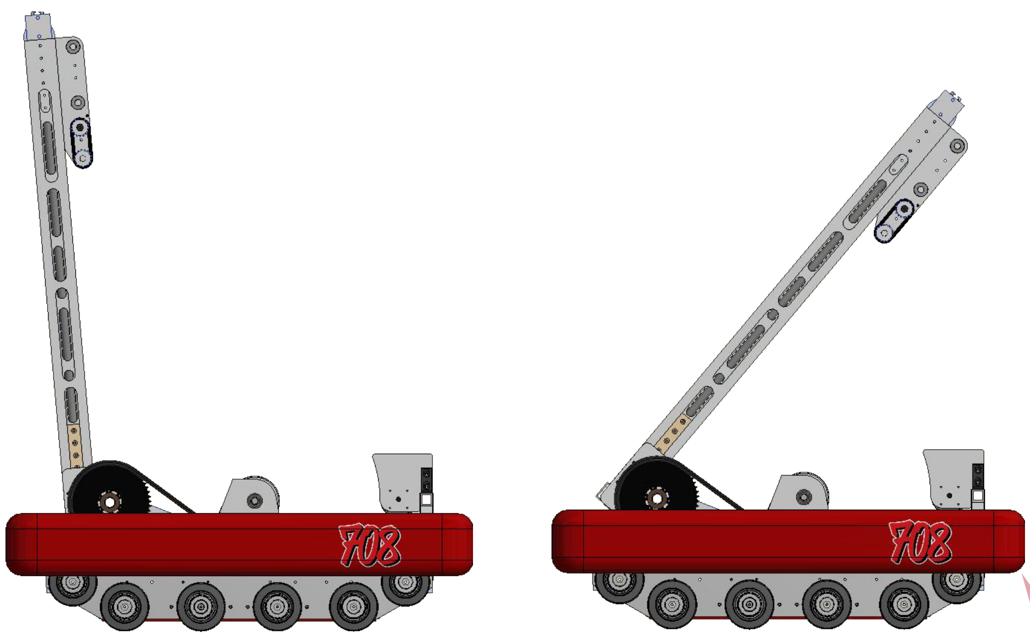
STRATEGY

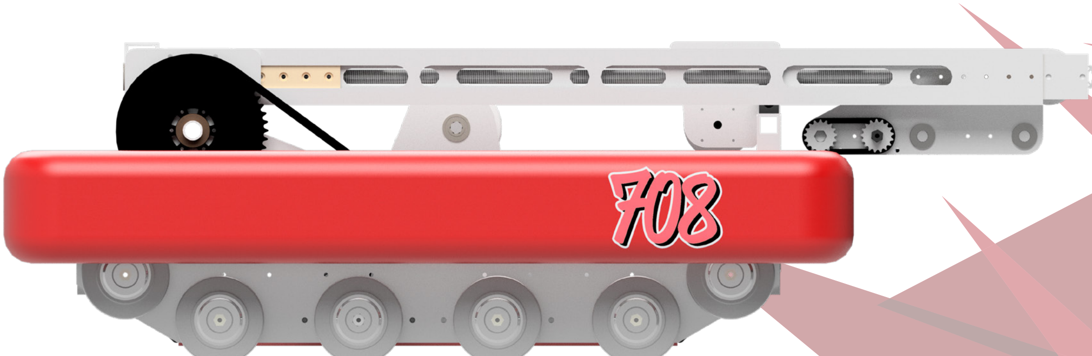
At the beginning of this season our team collectively decided what we wanted our robot to accomplish during this year's game. We decided it would be beneficial for our robot to shoot, scale, and breach all nine defenses. As we continued through the season, our robot was able to accomplish the goals we had set for it, with exceptions for the Cheval de Frise and the Drawbridge. Obtaining breach points by crossing defenses was an important strategy to our team due to the points earned from it.

After we talked about the design of the robot we discussed what autonomous modes we wanted to complete. In order to obtain maximum points, so our strategy was to cross the defense, and shoot in the high goal. However the defenses change each match, so we had to write multiple designed manipulators for the different defenses, and where they might be aligned. Ultimately our most successful program was to go through the low bar, as it was the only defense that remains consistent between matches, but we were also successful with other defenses that were drivetrain oriented.



Scouting every team is necessary so that we could come up with a strategy for our matches. We did both pit and match scouting in order to get the most accurate information on teams. With this information we use our pre match sheets to talk to other teams and create a plan for matches. When we discussed with the teams we would make up a strategy based on what autonomous modes we all could do then figure out how to get a full breach. If our teammates could breach a lot of defenses we would change our focus to scoring in the high goal and breaching a few defenses. If they could shoot accurately we would focus more on defenses. Lastly

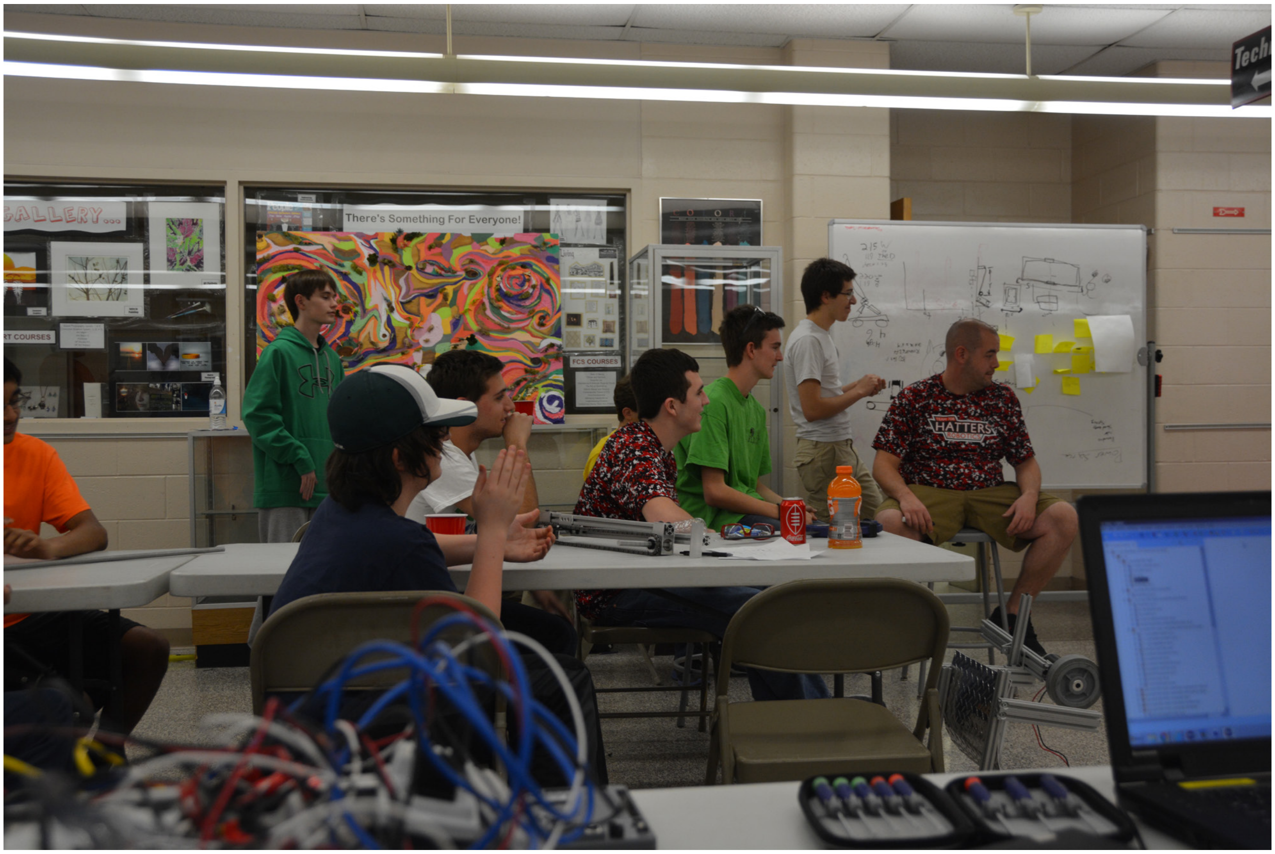




PROTOTYPING

Prototyping is a whole team event where every student works on a design they think will be best suited for the robot. This process occurs the first week of build season. During this week,no ideas are rejected. After Kick-Off, we sat down and read through the rules as a team to have a better understanding of the game. We keep track of rules that apply to each subteam in our engineering notebooks. After talking about all the ways to score different points everyone shared their initial ideas of mechanisms to complete the tasks of the game. We discussed different ideas for the drivetrain, intake, shooter, and hanger. We moved on from those initial thoughts to create lists of where the manipulator falls and into what category. From those lists, mechanical members from the team choose a project to lead. Other students on the team then picked which sub-team they were most interested in. Throughout the rest of the week, team members in each design team worked to create physical or computer generated models of their ideas so that weekend they would be able to explain their design to the rest of the team.

At the end of week, we presented our ideas to the team to make decisions on what everyone thought would work best. Some of the ideas were to use a four bar to get over and under the portcullis. Another idea was to use a telescoping mechanism to scale the tower. After all the ideas were presented, the core-design team, which consisted of about 10 students, sat down to discuss what prototypes would end up on the robot.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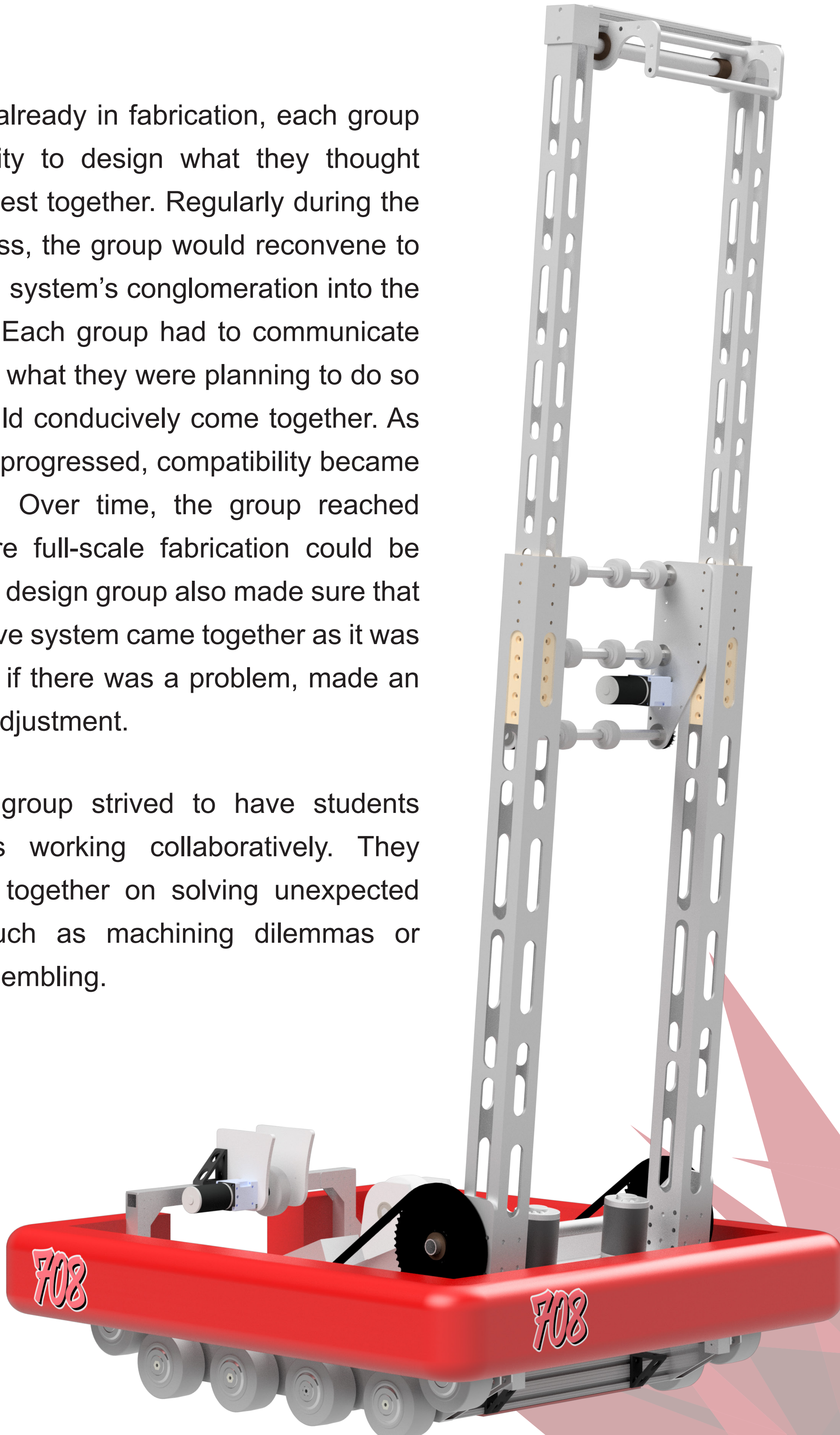
DESIGN PROCESS

A prototype is a practice design used to prove a concept. Students that acted as leaders during the prototyping process became the core design team. As the prototyping process has an organic-type leadership, it was easy to identify who served actively to lead each group. The core-design team, however, had a set leader named Thomas Abraham. It was the duty of the student who acted as the leader to ensure that the group maintains focus, the design is conglomerated well, maintain each sub-group, and to ensure the feasibility of each system and the overall robot. This design process was a new method of design for us, this year, and had great success. In the first meeting, all of the prototypes were put onto a board and were sorted through for feasibility. As no one could reject an idea during the first week, there were ideas that simply were not feasible. However,

it is still beneficial to not disregard ideas because ideas can be developed off of each other. With that complete, we then began to see which systems would perform best based off of the weighted-decision matrix that we made, with the whole team. That allowed us to see, without biased, which systems would operate the optimally. The design team then divided into smaller teams of a few kids and a mentor guiding them, each group working on a separate system. This subdivision allows mentors to work more closely with students and has students and mentors working together instead of one more-so than the other. The drive base being the only system already in fabrication, each group had the ability to design what they thought would work best together. Regularly during the design process, the group would reconvene to work on each system's conglomeration into the whole robot. Each group had to communicate to each other what they were planning to do so the robot could conducively come together. As each system progressed, compatibility became more critical. Over time, the group reached a point where full-scale fabrication could be started. Each design group also made sure that their respective system came together as it was designed, or, if there was a problem, made an appropriate adjustment.

The design group strived to have students and mentors working collaboratively. They also worked together on solving unexpected problems, such as machining dilemmas or problems assembling.



DRIVE TRAIN

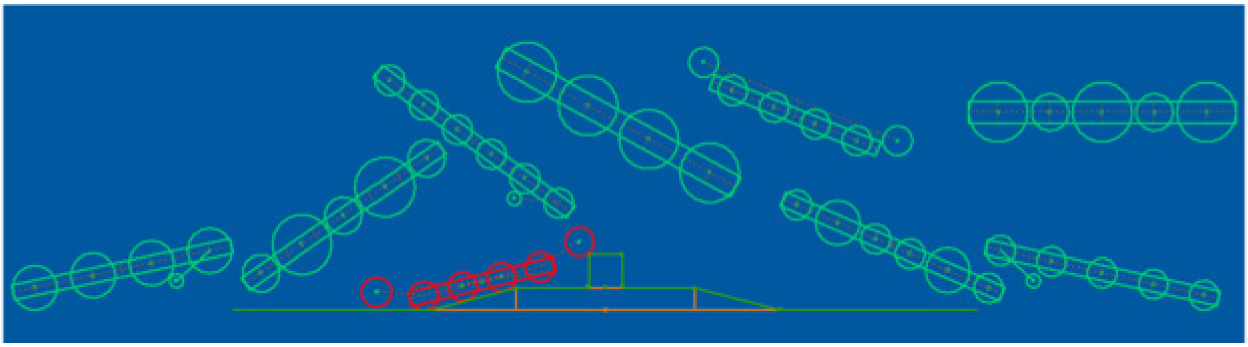
Our team decided that a highly-functioning and high-performance drivetrain would be vital to our success in this game when we weighted each of the ways to earn points in a weighted decision matrix. With that in mind, we went to work on our drivetrain immediately. Unlike the “physical prototyping approach” that other systems underwent, most of the conceptual ideas immediately began in the 3D design program, Autodesk Inventor.

The field and the barriers provided two entirely different friction surfaces. With some being polycarbonate, the ground could either be slippery or have plenty of traction depending on your location. With that in mind, we decided we wanted to stick with what wheels we knew to be reliable: High-Performance Colson Wheels. This is because these wheels have a relatively high coefficient of friction so they can grip the ground with ease. We would not have to worry about being pushed, pushing, or sliding.

The idea of using tank treads was quickly eliminated because tread does not handle sideload well and will chew up. Because of it’s thickness, it is also heavy.

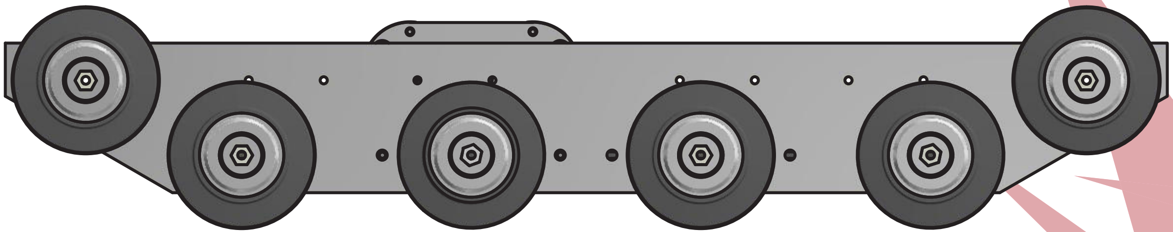
The obvious solution to overcoming barriers was larger wheels, however, we prioritized being able to drive underneath the Low Bar as a very important objective, and big wheels would act as a hindrance to completing that objective. In conjunction to that, as we looked more into the wheel sizes, we noticed that bigger wheels would inherently add more weight to the drivetrain. Traditionally, our team tries to place drivetrains around 30-40 lbs. This balance provides enough low-to-the-ground weight that tipping isn’t a concern, yet, is not so heavy that other systems must be nerfed.

We quickly realized that having many, bigger wheels was unrealistic so we began our process on wheel combinations and configurations. We, as a team, identified the rockwall to be the hardest to get over geometrically, so, we used that for design.



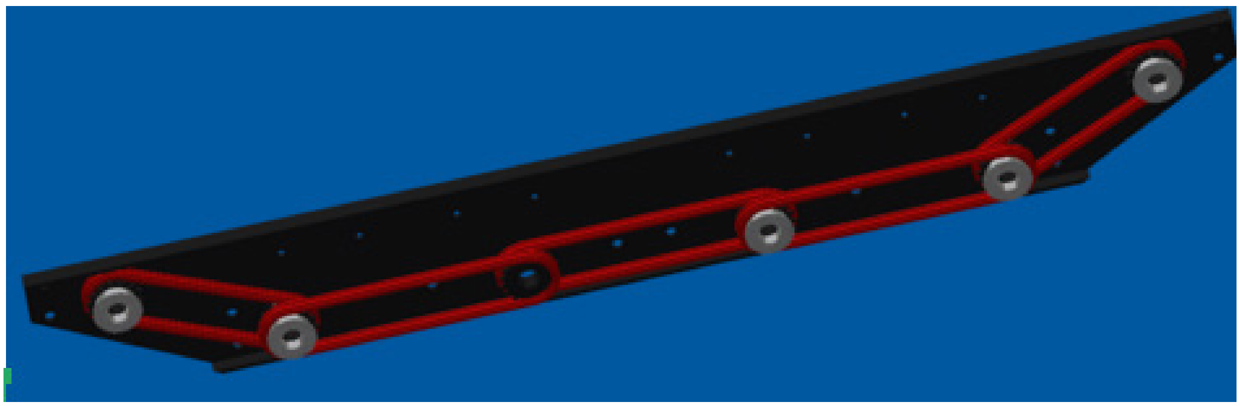
Each rail shows a few of the many conceptual ideas that we went through. The one in red represents what decision we made. The drive rail would have 4 inch wheels on a large drop center of 1 inch. The wheels would be 2 inches wide so we did not lodge the wheels in between the blocks in the Rough Terrain. Most of our time was spent deciding what the configuration would be. Once we knew that, power transmission was easy.

Each wheel is powered so they may all help to pull the robot over the barriers. You can never have enough space inside the robot so we tried to package the transmission as much as possible.

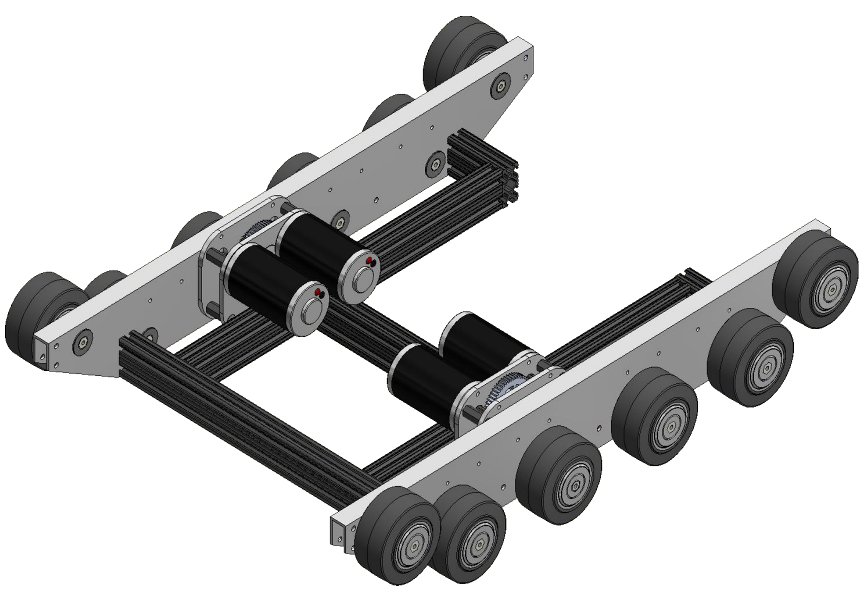


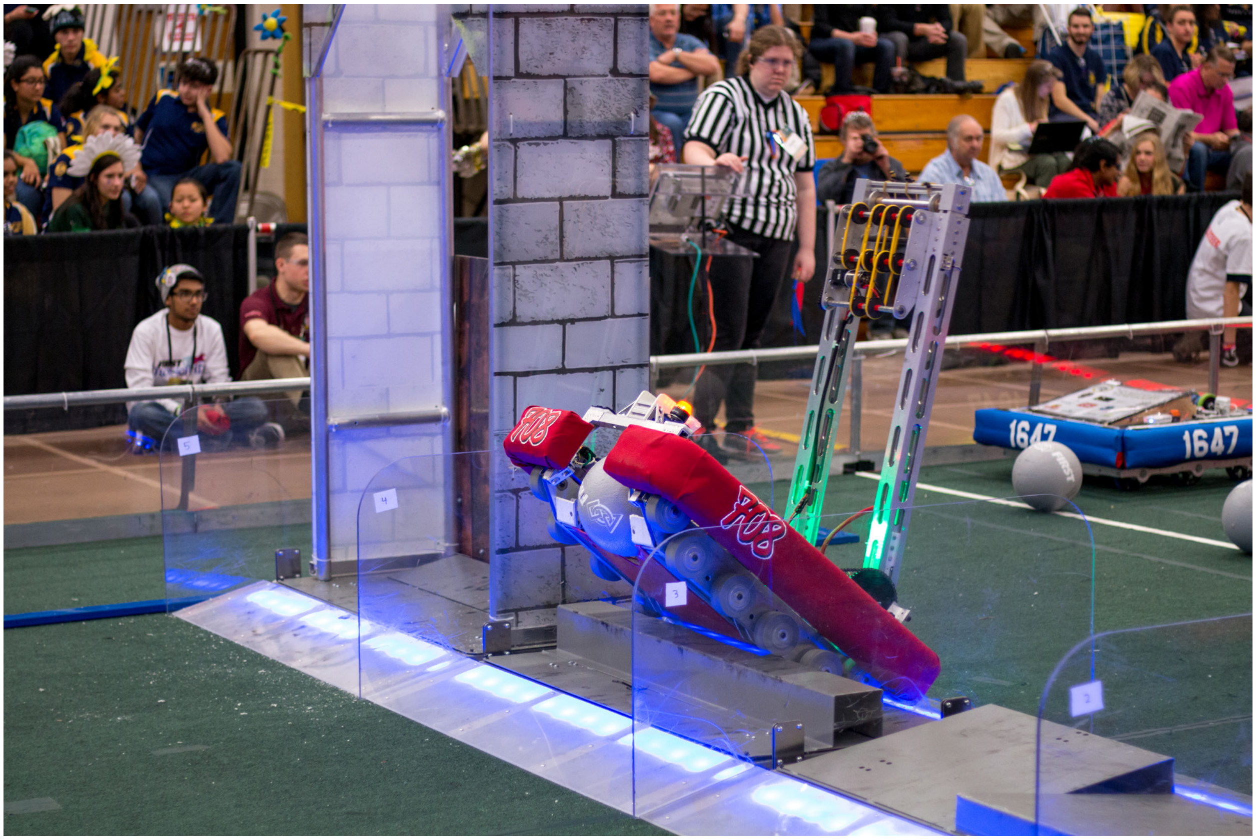
DRIVE TRAIN

Shown was a view of the framing/driverail component. Chain is run inside a boxtube which had its view cut in half so the chain can be viewed. Wheels are cantilevered out of the boxtube.



The gearbox feeds into the boxtube and chain runs through the boxtube as seen previously. Assembly for this design can be a bit tricky, however, the chain rarely needs to be serviced if done correctly due to the shielding.

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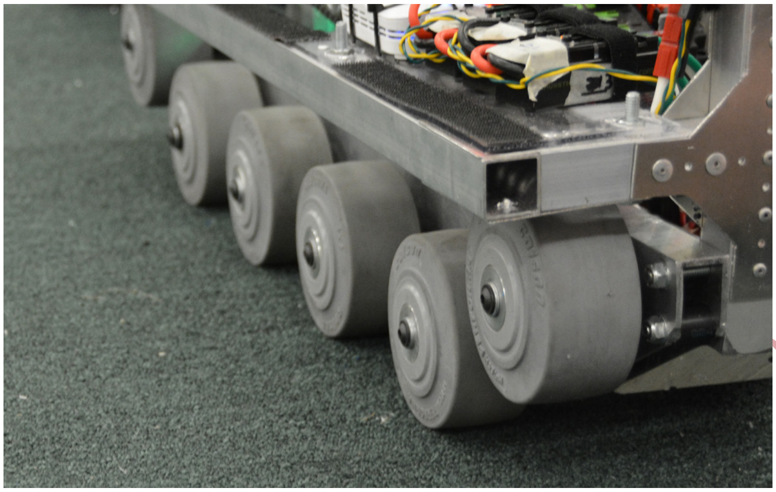
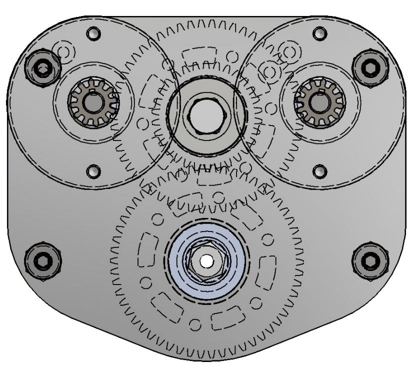
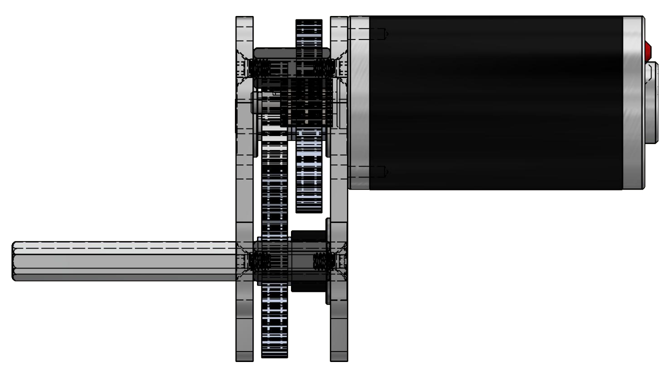


DRIVE TRAIN

Now that we knew how the wheels were going to be powered, the gearbox was the last major subsystem left.

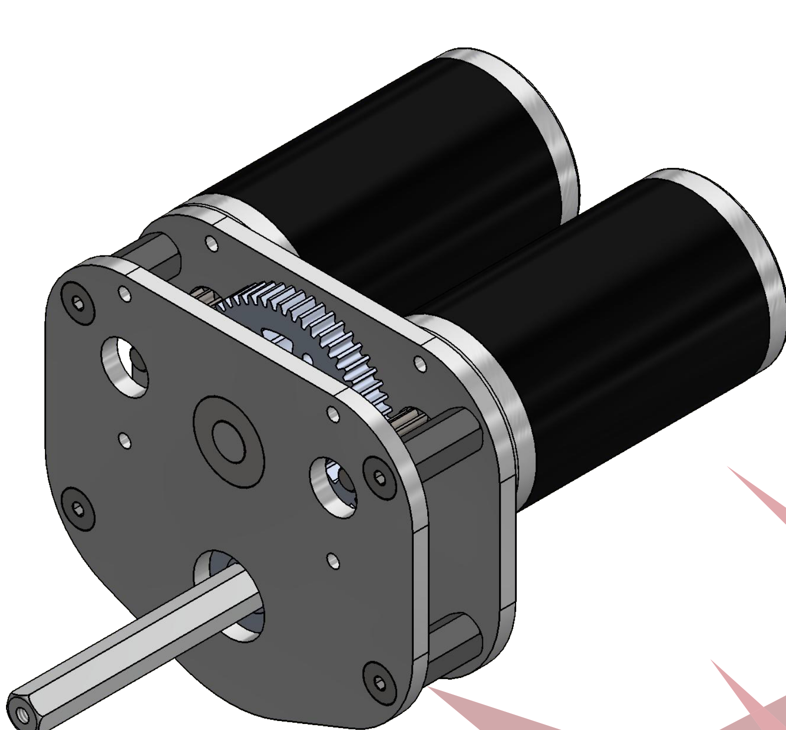
The gearbox was comparatively simple to the rest of the drive train's design process. Two CIMs feed in with 12 tooth gears. These 12 tooth gears mesh with a 54. On the same shaft as that 54 tooth gear is a 30 tooth. The 30 tooth powers another 54. The second stage, 30-54 can have gears swapped out in a few directions to have more torque or more speed in the drivetrain. There was a lot of debate over having two CIMs or three CIMS. Ultimately, we decided to go with two due to spacing, weight, and spreadsheet data.





1-Speed Drivetrain

	Free Speed (RPM)	Stall Torque (N*m)	Stall Current (Amp)	Free Current (Amp)	Speed Loss Constant	Drivetrain Efficiency
CIM	5330	2.41	131	2.7	81%	90%
# Gearboxes in Drivetrain	# Motors per Gearbox		Total Weight (lbs)	Weight on Driven Wheels	Wheel Dia. (in)	Wheel Coeff
2	2		154	100%	4	1.1
Driving Gear	Driven Gear		Drivetrain Free-Speed	Drivetrain Adjusted Speed	"Pushing" Current Draw per Motor	
12	54		11.48 ft/s	9.30 ft/s	72.59 Amps	
30	54		8.10 : 1	<-- Overall Gear Ratio		
1	1					
1	1					



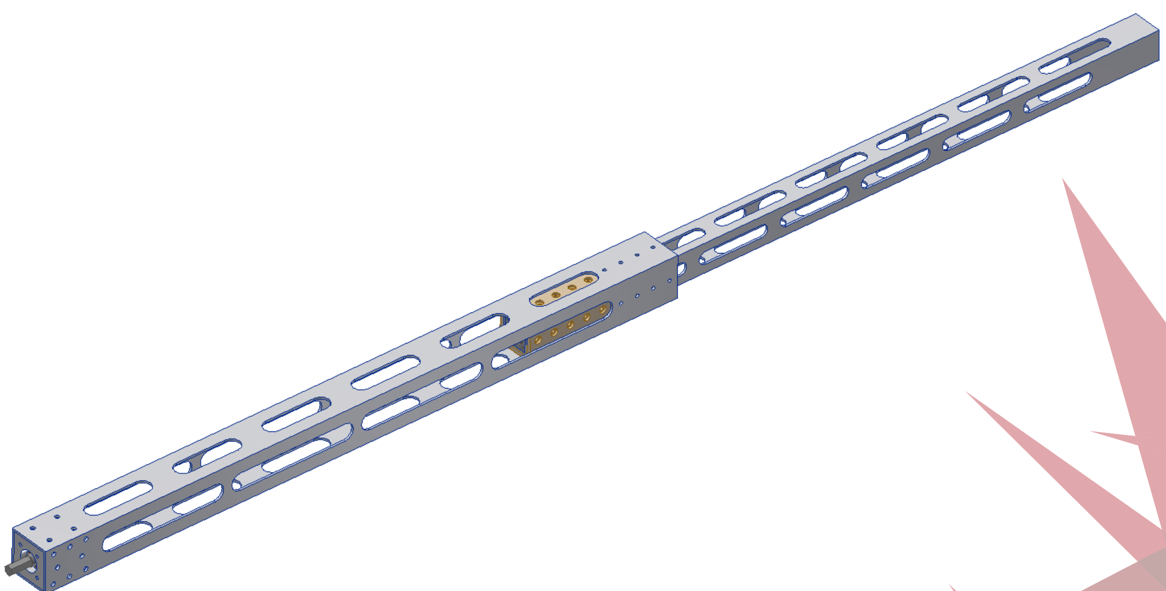
ARM

The arm is designed to scale the tower, using a single stage telescoping tube in tube configuration. Our initial prototype of a scaling contraption consisted of two pieces of 80/20 that used chain to transfer power from the base to the extension. The location of the arm could not interfere with our shooter, must maintain a low profile so that we could traverse the low bar, be strong enough for repeated use and accomplish the scale in under seven seconds. The mounting location and corresponding pivot had to be opposite the intake system requiring a clear span through the center of the robot. This allowed the arm to extend past the frame of the robot, and gave a nice spot to mount the intake system.

The student lead on the arm assembly was concerned about not having enough skill to draft the design of the arm, but with the help of a mentor and other students on the team the design came together. There was significant trial and error in the design of the arm. The geometry of the swing required combined with constraints from other systems required numerous iterations of the arm assembly in CAD.

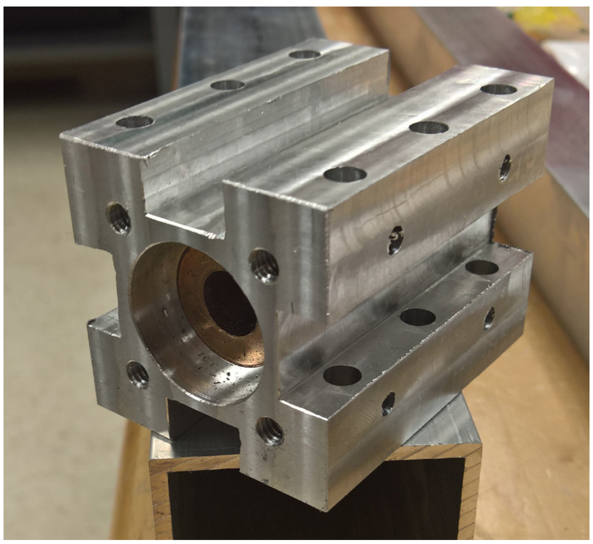
The original plan to power the arm was to use ANSI #35 chain to accomplish the lift. Chain is linear in nature, easily replaceable and familiar to our team. However, with significant size constraints and mounting configuration problems we abandoned the chain powered hanger in favor of a precision acme screw design. The screw has eight starts which provides one inch of linear motion for each full revolution of the screw.

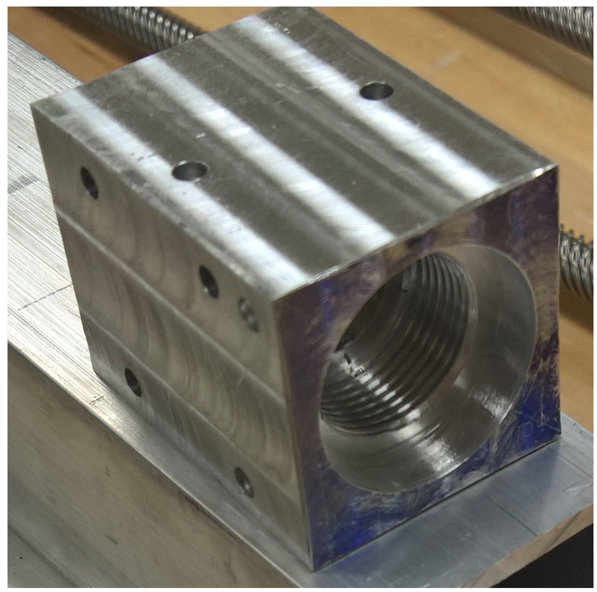
As the general design of the arm came together, there were space and configuration issues with multiple systems occupying the same critical space. In order for the shooter to function properly it needed at least 14 inches of clearance between the arm rails. There were also considerations about the intake needing to go wide to ensure proper boulder pickup.

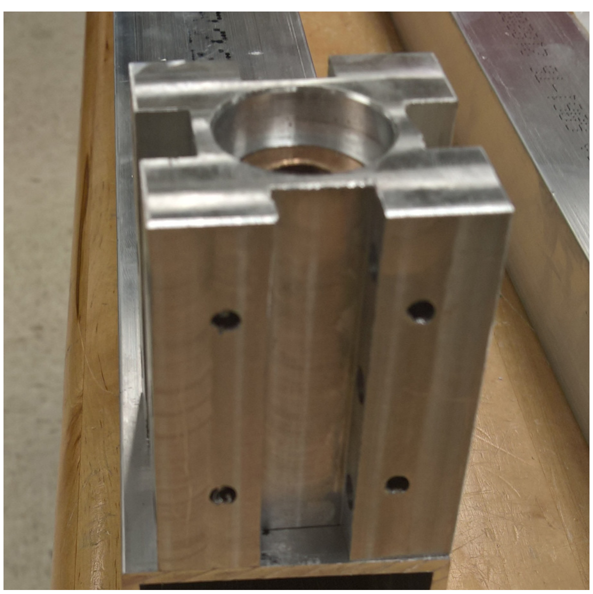


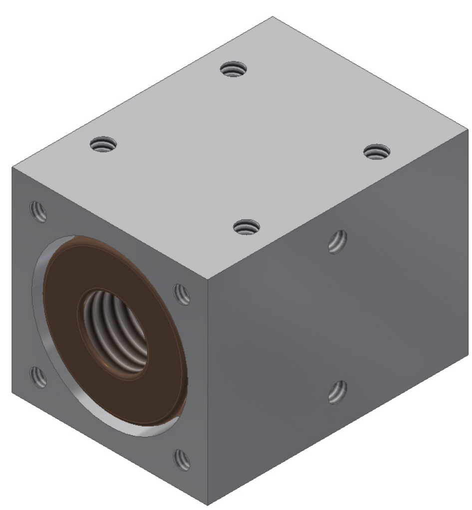
ARM

Once the team decided the general parameters, and space configuration of the robot the arm design was ready to go into final drafting. Final drafting of the arm consisted of redrawing the assembly piece by piece to ensure proper fits and clearances. We again started with the largest constraint which is the ACME Nut. The nut has a specific size and thread taper that is not easily modifiable. The nut block, that interfaces with the inner rail was then designed to be a tight fit with 1.5" x 1.5" square tubing. Numerous pattern cuts were introduced in this step to ensure proper lightening of the system while still ensuring a very robust system.

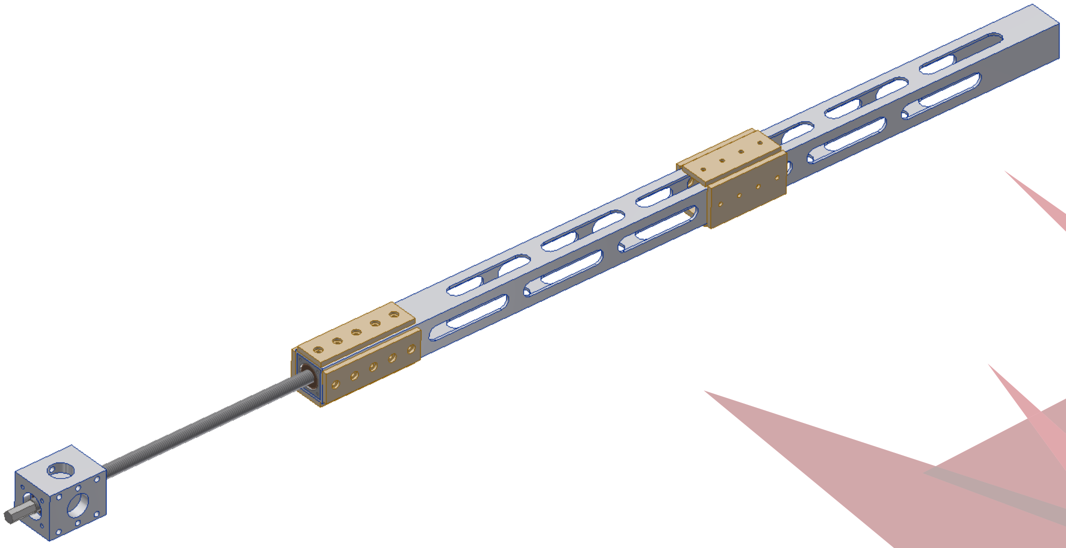






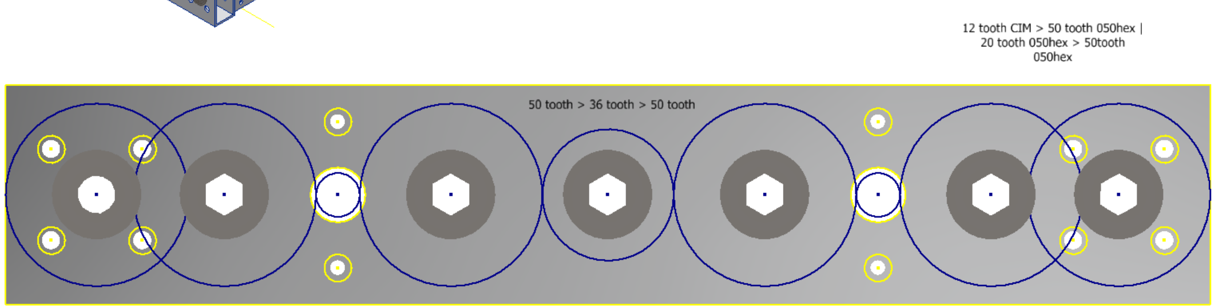


The outer rail of the arm is constructed of 2.25” x 2.25” square 6061-T6 aluminum tubing. This size tubing allowed for ¼” High Density Polyethylene bearing surfaces on all friction sides. The real issues arose when trying to attach the bearing pads to the inside and outside of the outer and inner tubes. Taping 32 number eight bolt holes did not seem logical or time effective. The design team found Aluminum Chicago Bolts which nicely clamped the bearing pads to the aluminum tube. These would later prove to be difficult and time consuming to work with, and were eventually replaced with stainless steel posts due to numerous stripped #0 flat head slots.

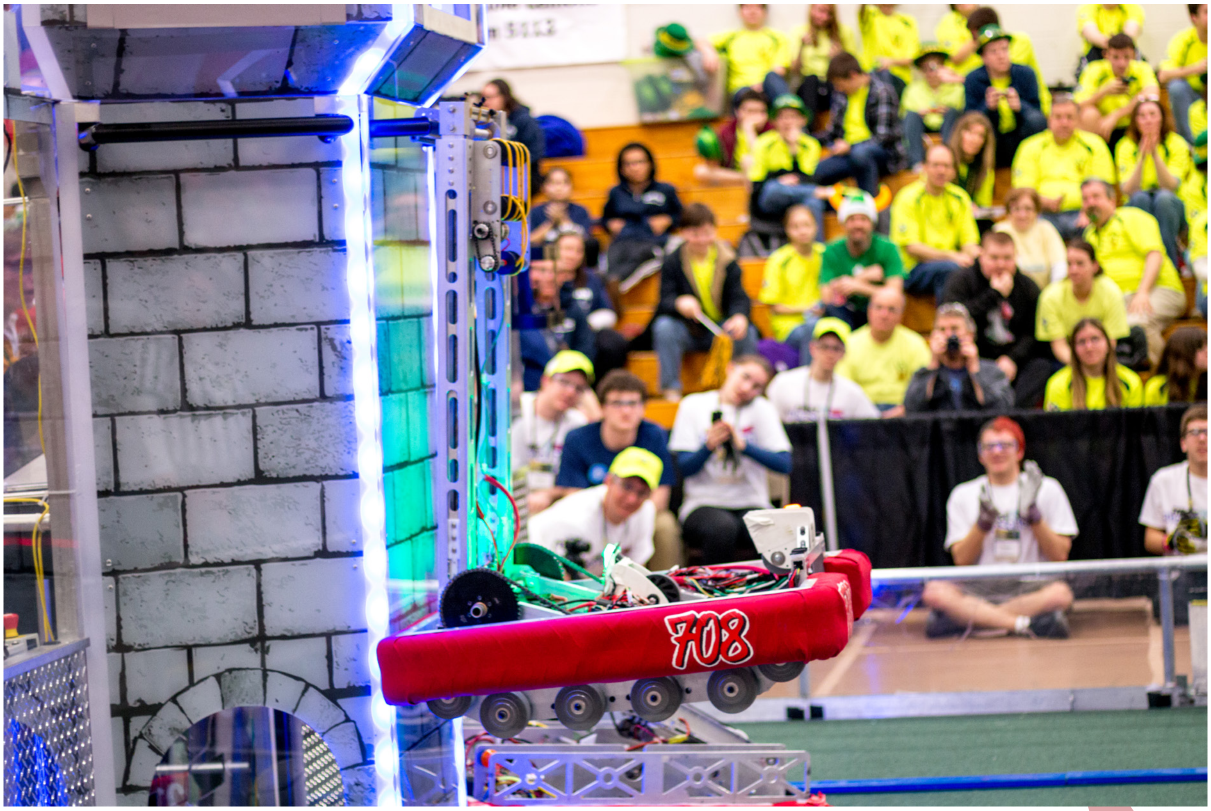


ARM

Inside the Outer Rail is the Lower Bushing block that also doubles as the pivot point of the arm system. The design team knew that this point was the most critical in the system. This 2.25” x 2.25” x 3” block of aluminum not only needed to allow the precision ACME screw to pass through the block, but would also act as the mounting location for the arms. This lower bushing block went through several iterations until a suitable design was found. There were numerous clearance issues that need to be accounted for in the manufacturing process. In fact, the first block that was manufactured was severely out of tolerance, which provided a tough lesson for some of the manufacturing team.



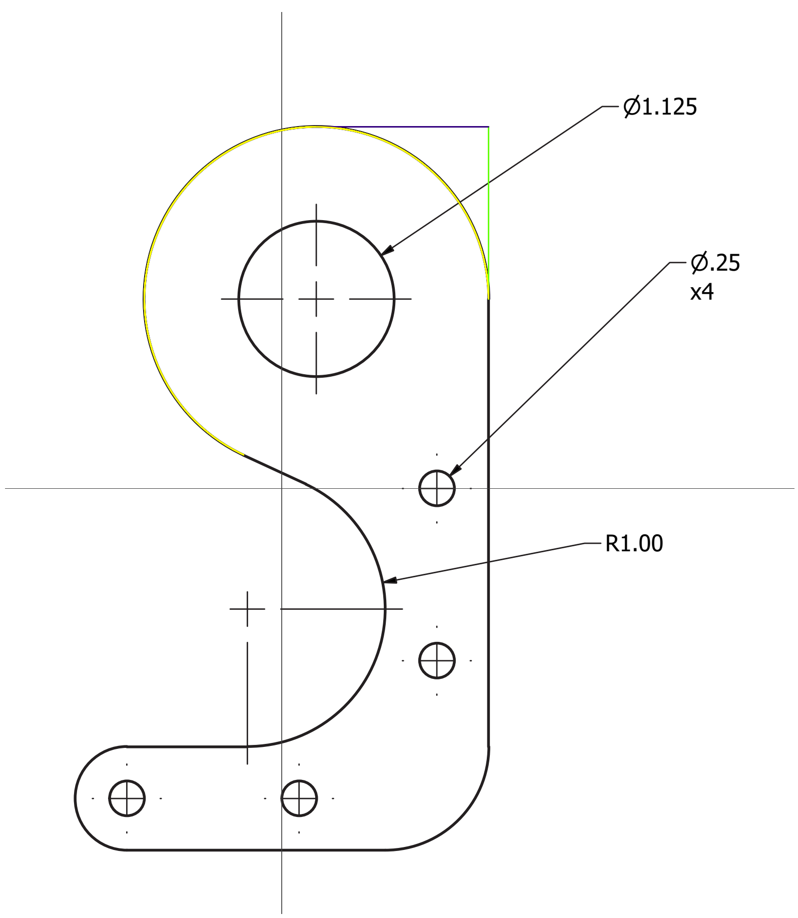
With the linear motion of the arms determined the design team had to determine how to properly convert the rotational motion of the 2 Mini-CIM motors into something that would affective and easily spin the ACME precision screw. A gear ratio of about 10:1 was determined to provide the necessary force and speed to ensure a successful scale. With numerous complex gear configurations, the design team found it necessary to shift the CIM motor mount to a non-linear alignment, which dropped the CIM Motor just shy of a half inch off the center-line of the arm gearbox.

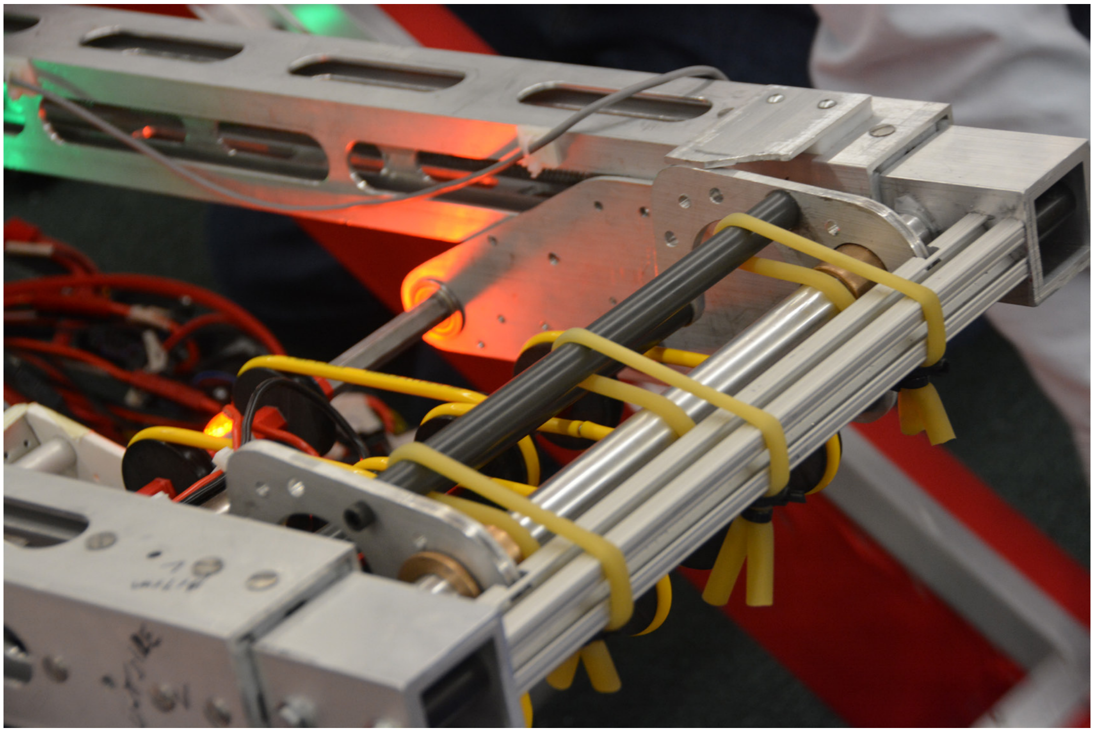


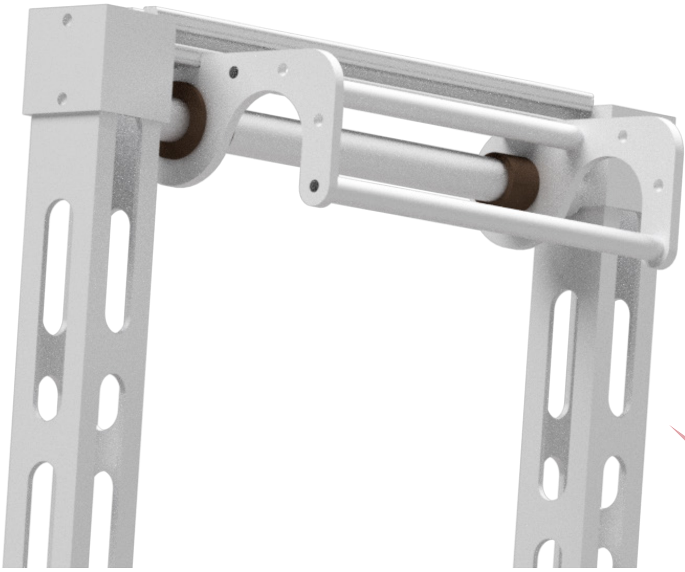
ARM HOOK

The hook on the arm is constructed from ¼" Aluminum plate to ensure that it had the rigidity to support the robot's weight. The hook uses aluminum cross members to ensure that the entire weight of the robot is supported by both hooks and therefore both arms. The hook needed to be spring loaded to ensure that it would not catch on the low bar while crossing the defenses. A quarter inch plate was constructed to retain the hook until the arm is extended from its contracted state ensuring that the hook would not entangle with the cross member. The simplest stored energy to power the hooks was determined to be surgical tubing, which contracts at a predictable rate when equal lengths and tension is applied.

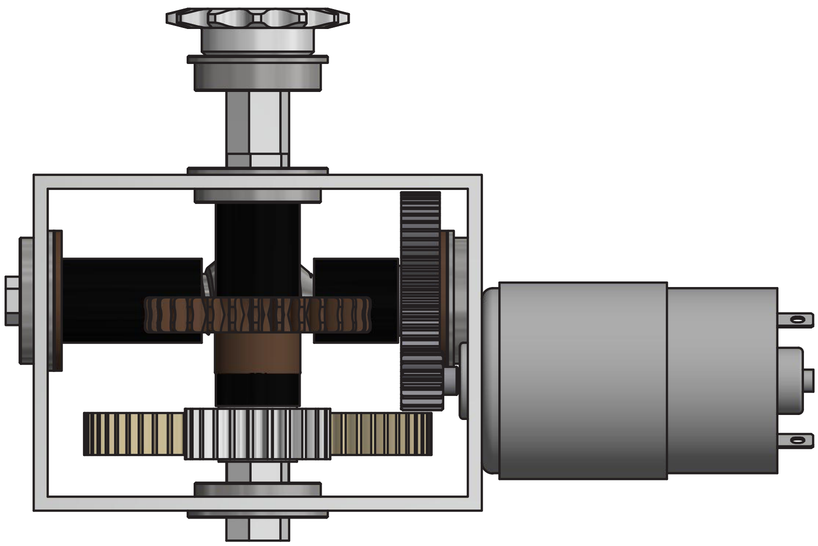
The arm assembly is a testament to trial and error, with numerous reconfigurations to ensure that the other systems on the robot could occupy the necessary areas and ensure proper operations through multiple scheduled events.

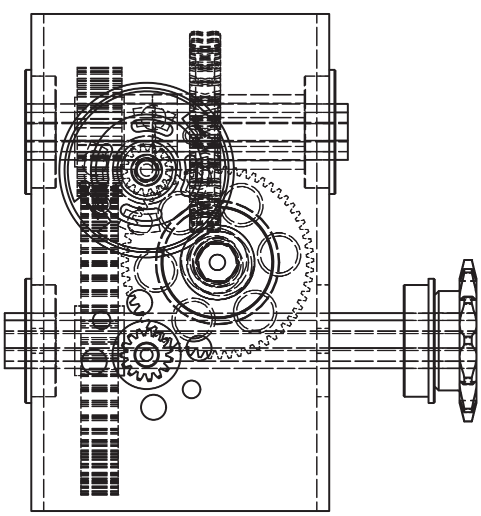


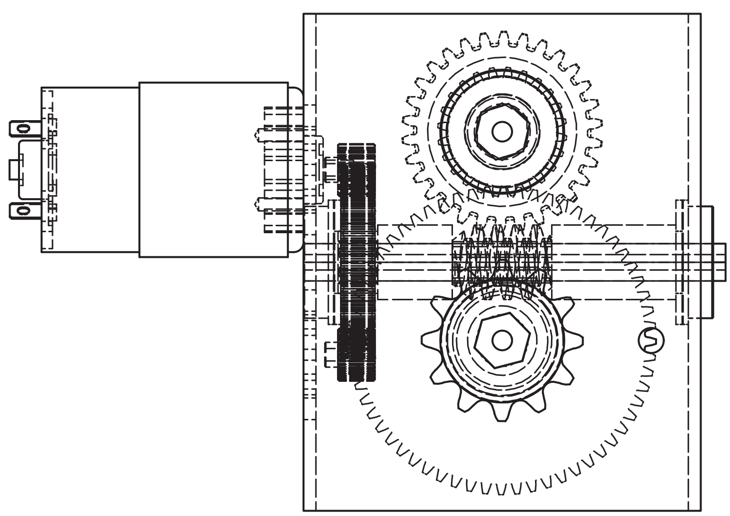


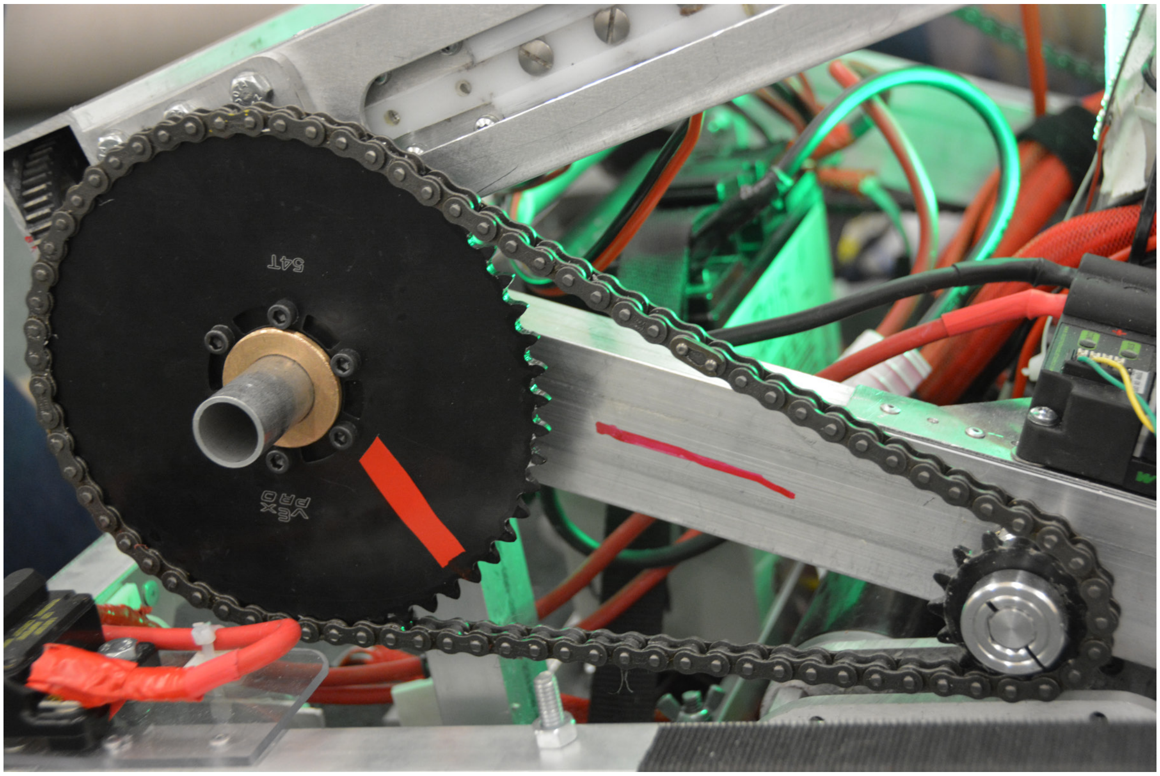


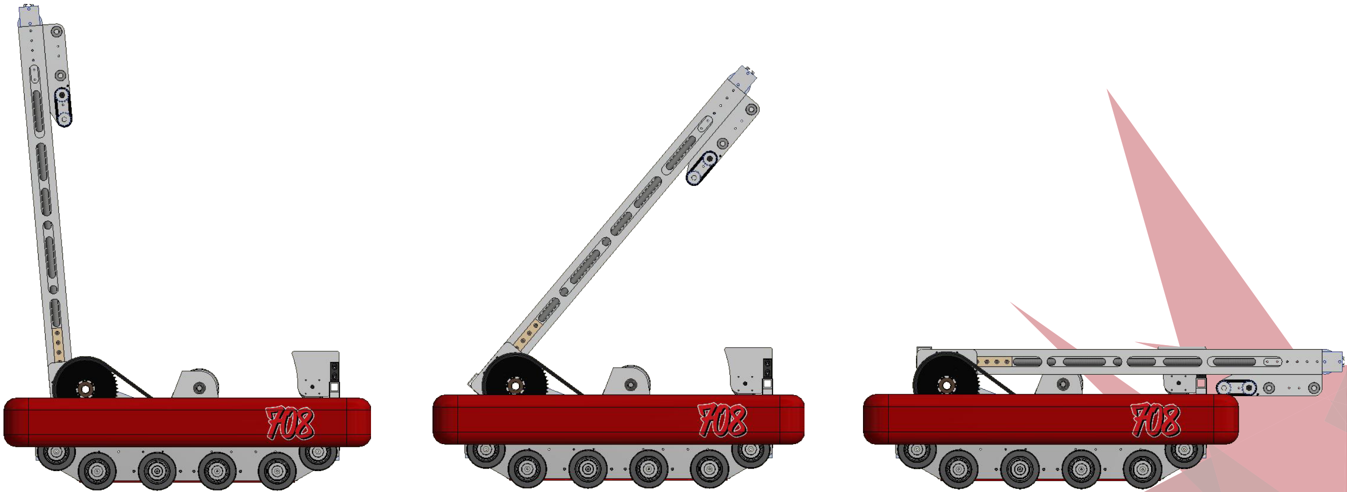
ARM PIVOT





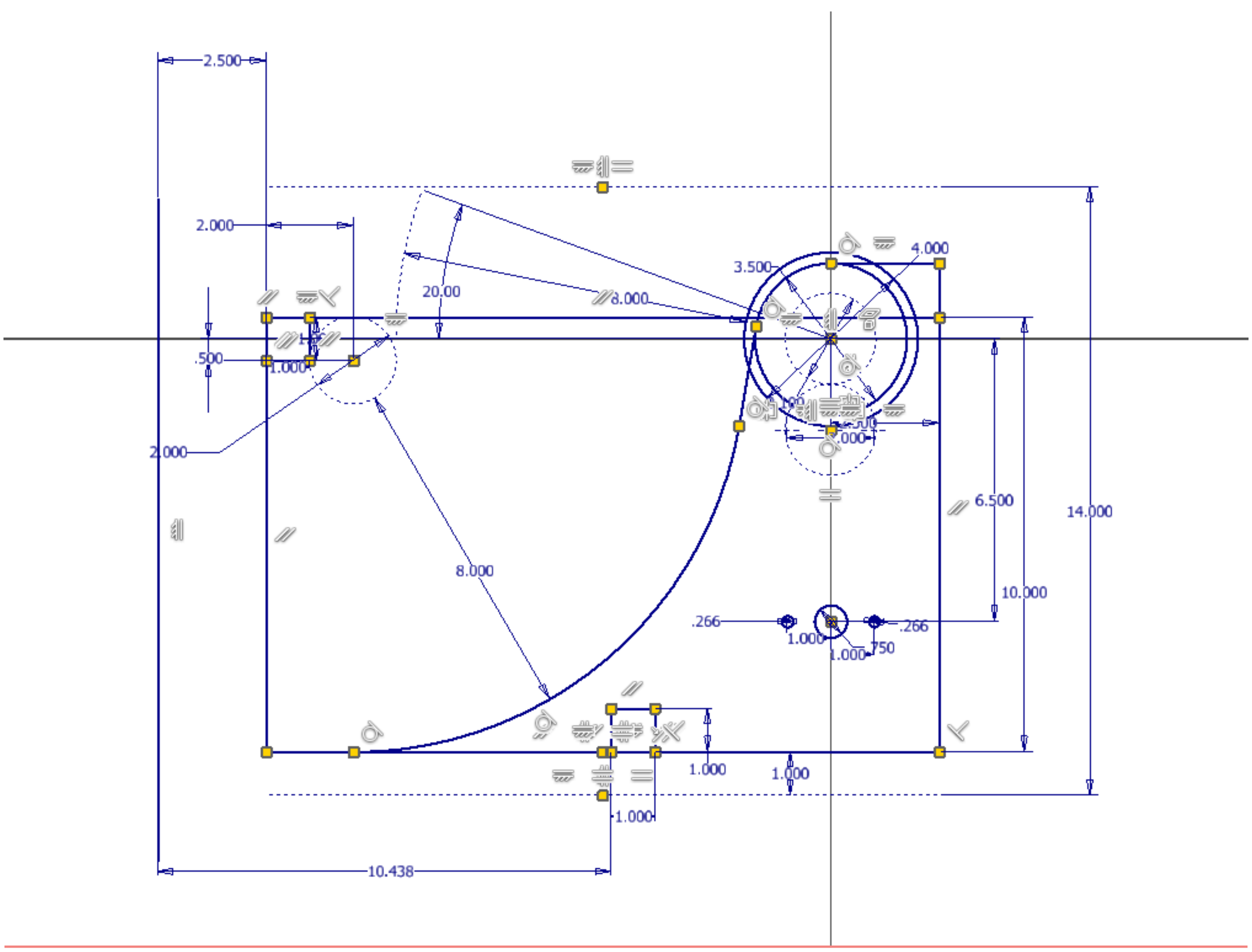






SHOOTER DESIGN

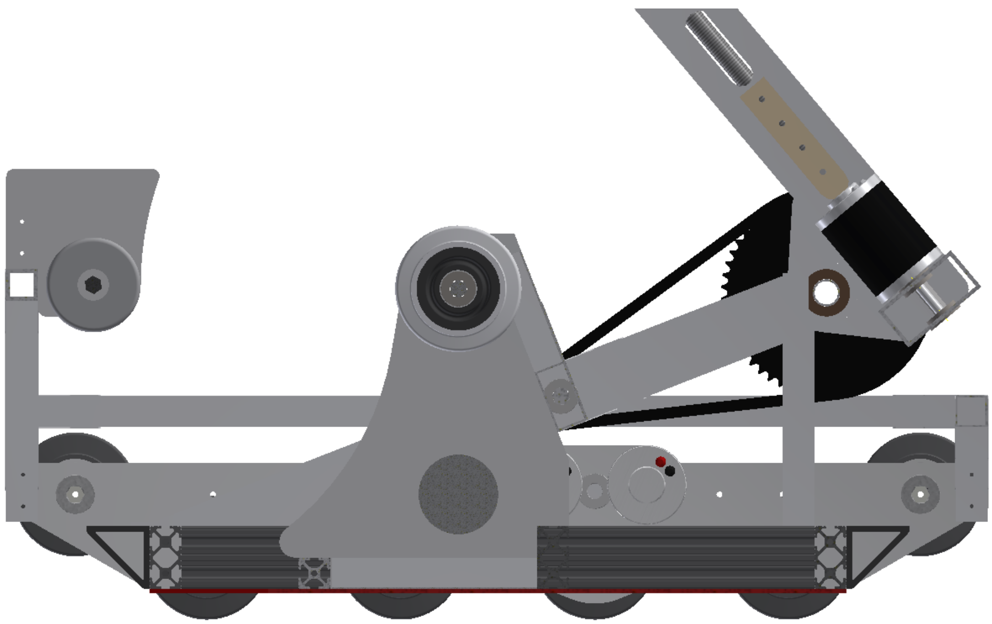
During the first week of build season we prototyped a flywheel for our shooter using a Colson wheel. In the initial design meeting, we decided that the optimal place to shoot from would be the bottom of the batter, as it is a set point that is close enough to the tower and would make aiming the robot easier and will not make too much of a difference when shooting from farther away. At that point we determined the distance from the tower, the height of the goal, and the speed of our wheel. We then applied those numbers to the basic kinematic equations, did some quick physics and determined our optimal shooting angle. From there we jumped into CAD and tried to work around our constraints: it cannot be taller than 15” and we must shoot out the same side we intake from. We then laid out the 2D geometry for the shape of the shooter. After many different ideas, it was determined that meeting both constraints was impossible. As a result, we dropped the constraint of shooting out the same side as the intake. This made the geometry much simpler and easier to work with.

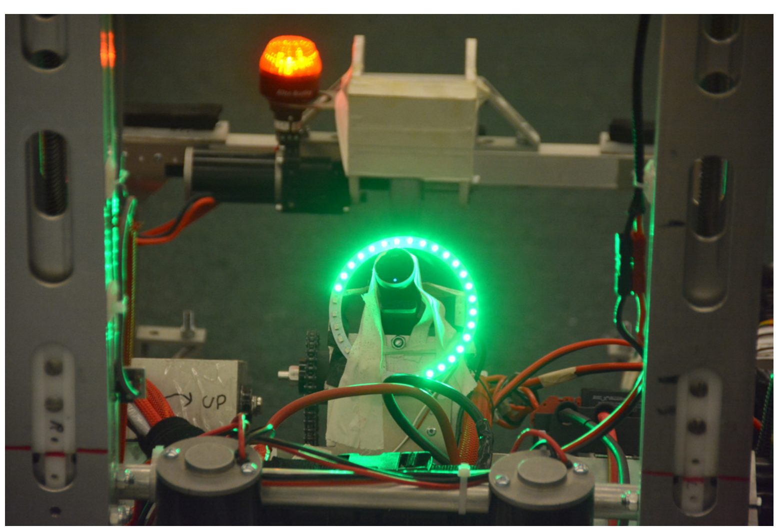


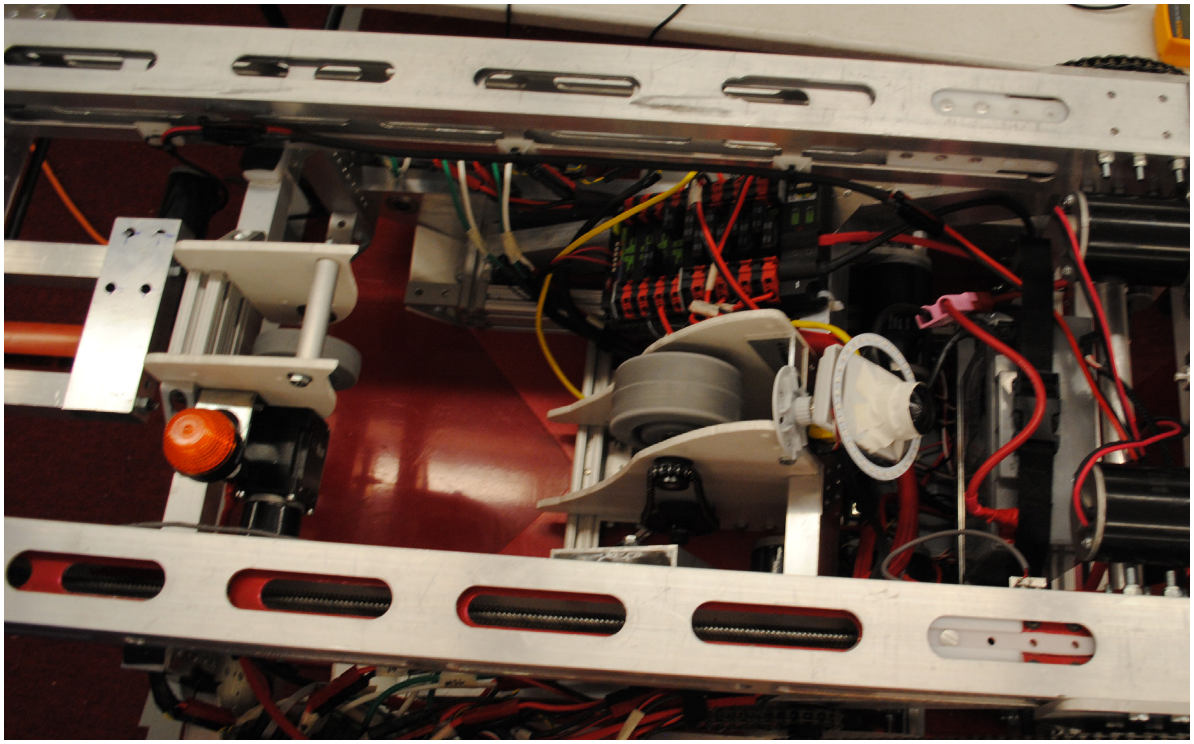
Once the initial geometry was figured out, we moved to making a 3D model and prototypes. Through this process we made multiple different iterations changing variables such as ball compression and wheel size. When we developed a design in CAD that we were happy with we printed it out, made the plates and assembled the prototype. Ultimately we decided on “a bunch of compression” and a four inch wheel. Later we decided to add a flex grip drive roller that expands as we increase the speed. Also after playing some matches we realized each ball had a different texture, and the angle that they were being shot at varied. To make our shooter adjustable, we are able to add and remove metal plates to adjust the angle the balls are being shot at.

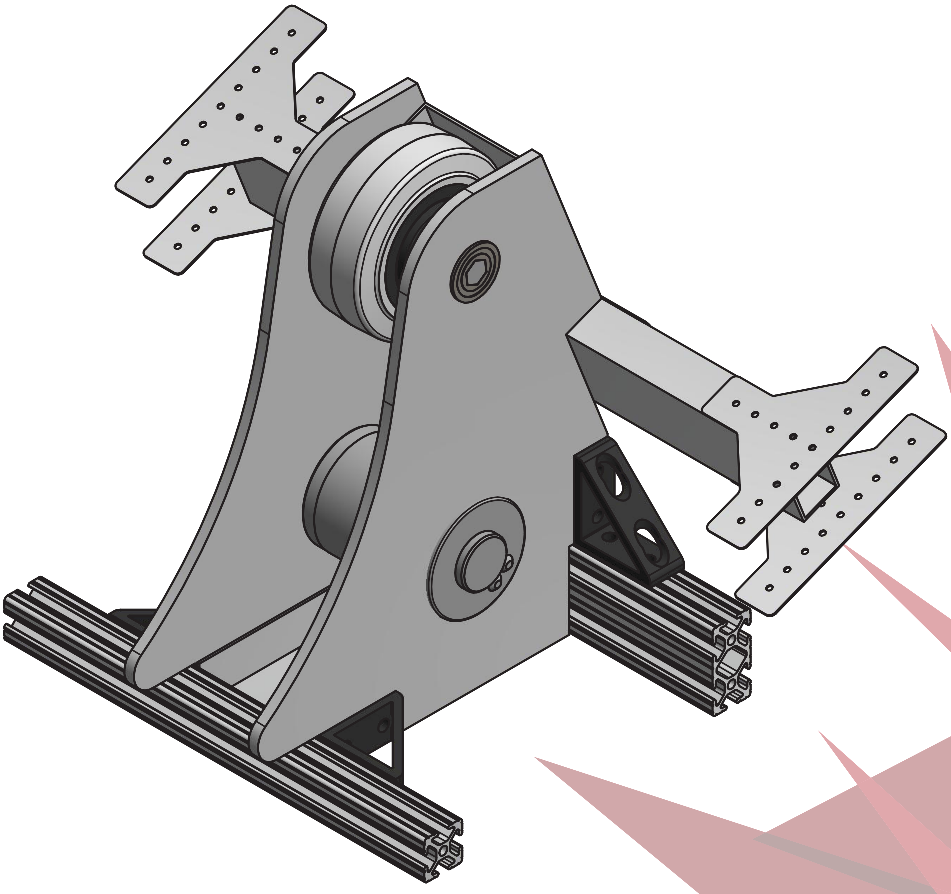
SHOOTER

Another part of the shooter is the feeder wheel. A transition stage for the ball between the intake and the shooter. It also angles the balls for when they are being shot. The loader works with an Infrared Sensor to detect the balls and the position they must be in for accurate shots. Also the camera is mounted on the back of the loader inside an LED ring that locates the high goals with retroreflective tape.



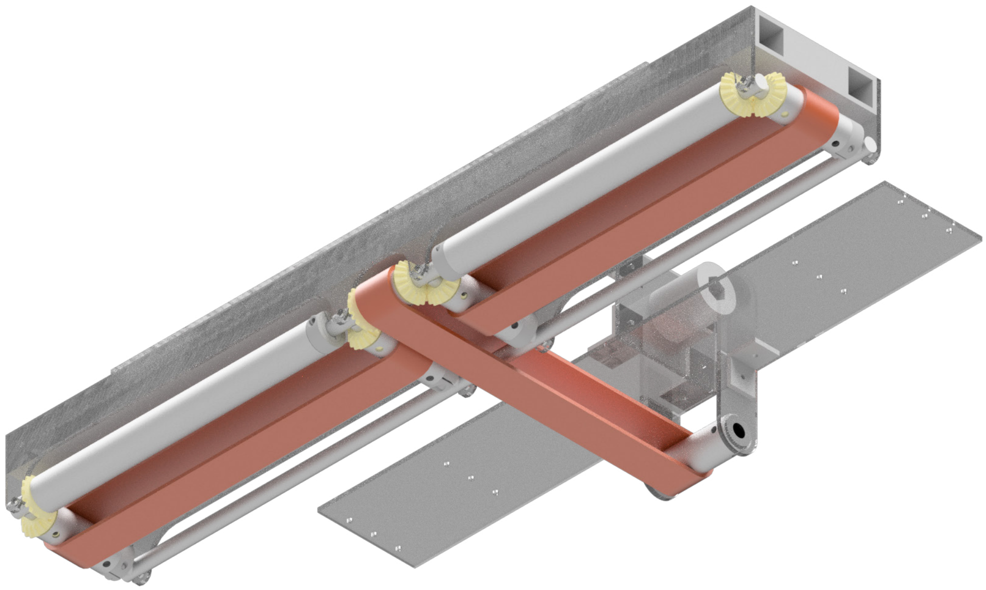






INTAKE DESIGN

The intake on our robot is attached to the front of the hanger, and allows us to obtain balls efficiently. In the beginning of the season we started out with a roller intake. We also had conversations whether we wanted the intake to go over or under the bumpers. Instead we decided to eliminate the bumpers in that area, and have the intake go in the middle so that the boulders can pass through with ease into the shooter. Next we took a look at our off season robot that we built this summer, and the intake we used for it. The robot used high friction urethane belts to intake the balls, and this design worked efficiently, so we decided to use belts for the intake this year. We choose to have the rollers pull the belts linear and horizontal so that we could grasp the ball from any angle. We measured the width of the robot to see how far apart we needed to make the rollers without exceeding the perimeter borders. We also settled on smaller rollers to reduce weight and bulk on the intake.



Once we started to construct the intake we used bevel gears but found a problem with that. The gears would rip apart the balls or block the ball from powered intake. Also the belt was not pulling in the balls as efficiently as we wanted. Towards the end of built we decided to refresh the entire intake concept and come up with a new design using rollers connected by polycord. All of them were linear this time instead of some changing direction with complex bevel gears. This design produced a more successful outcome and we were more efficient at intaking balls. Also there were no tears in the balls with this design. After our first competition, we replaced the polycord with a series of small diameter high-traction colson wheels.

The gearbox for the intake we are using was originally designed to be used with an Andymark motor, but the gearbox was unreliable, so we settled on a motor with more Versatile Planetary, a RS775 motor.

INTAKE

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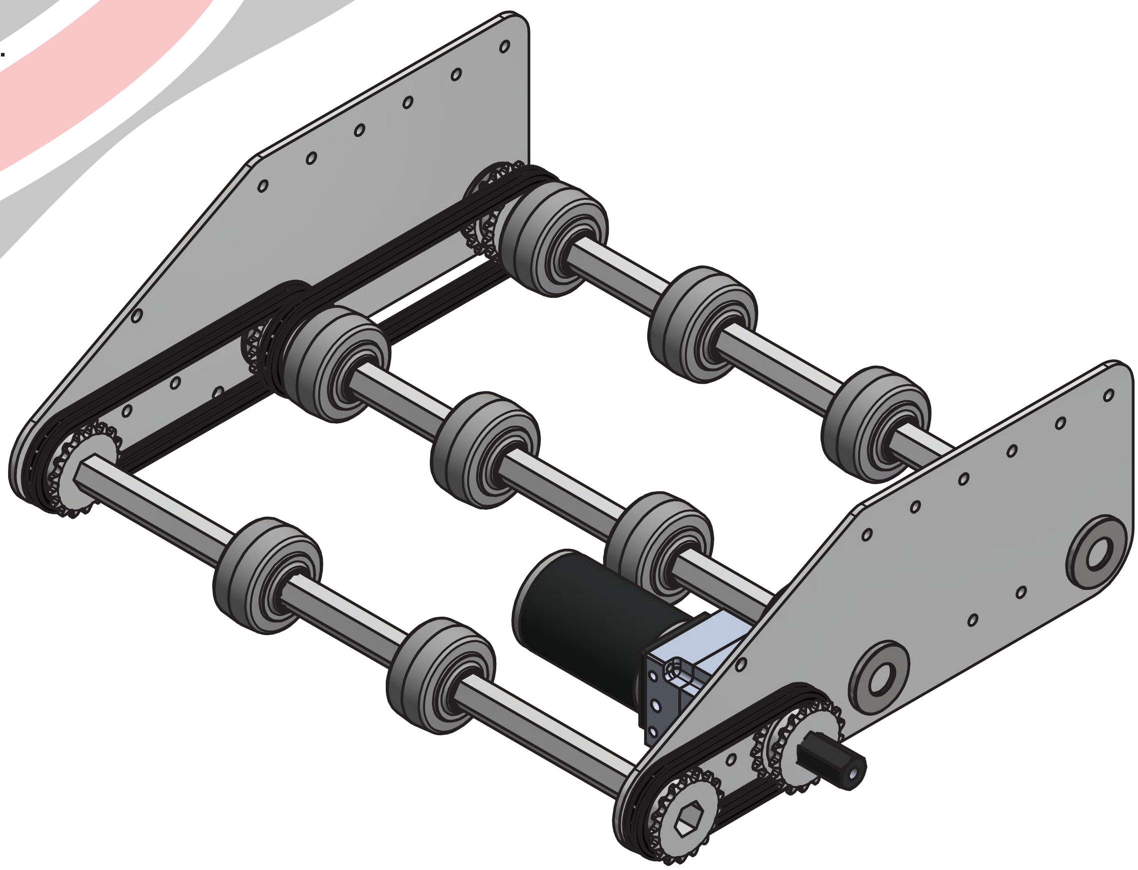
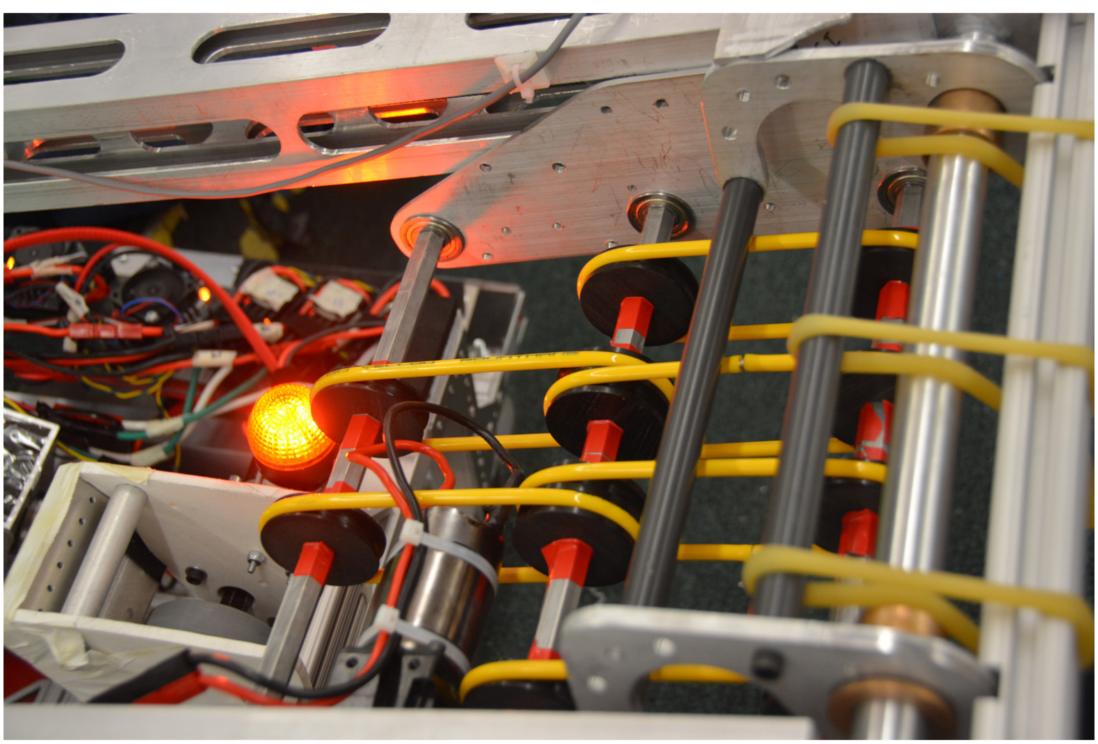
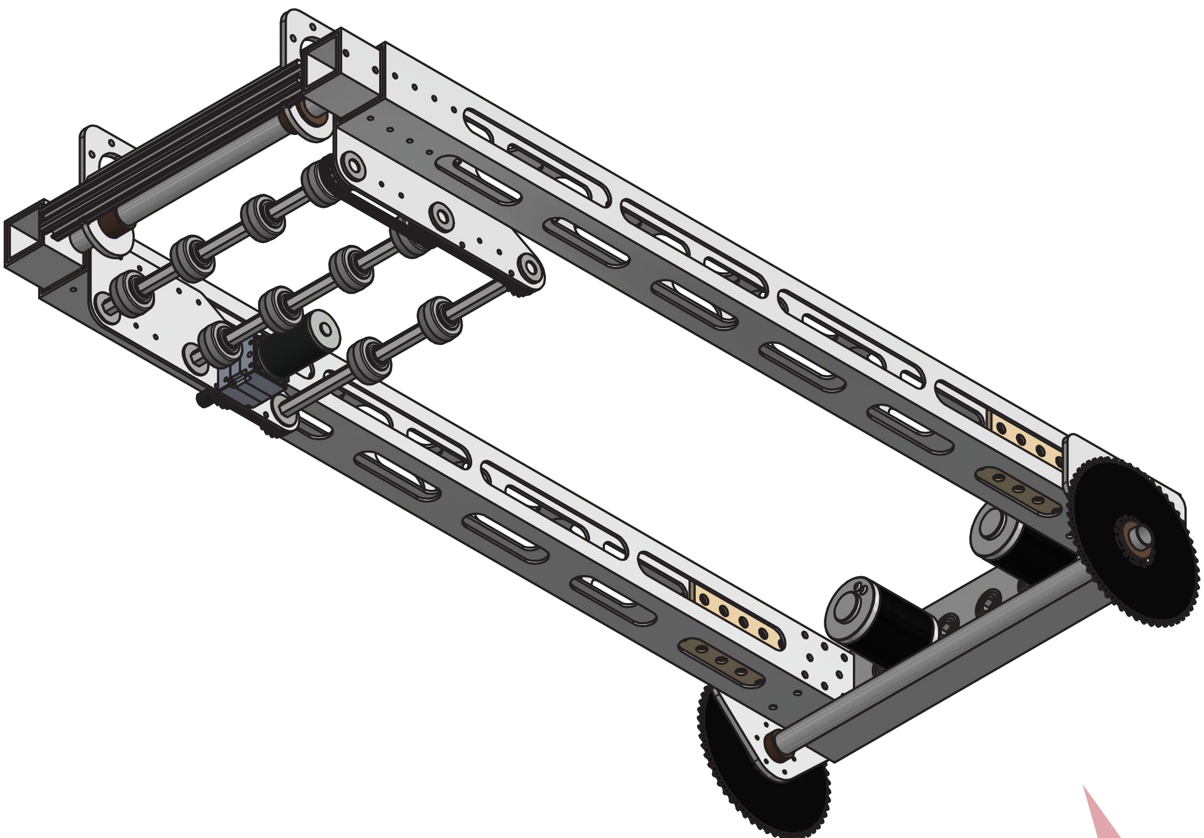
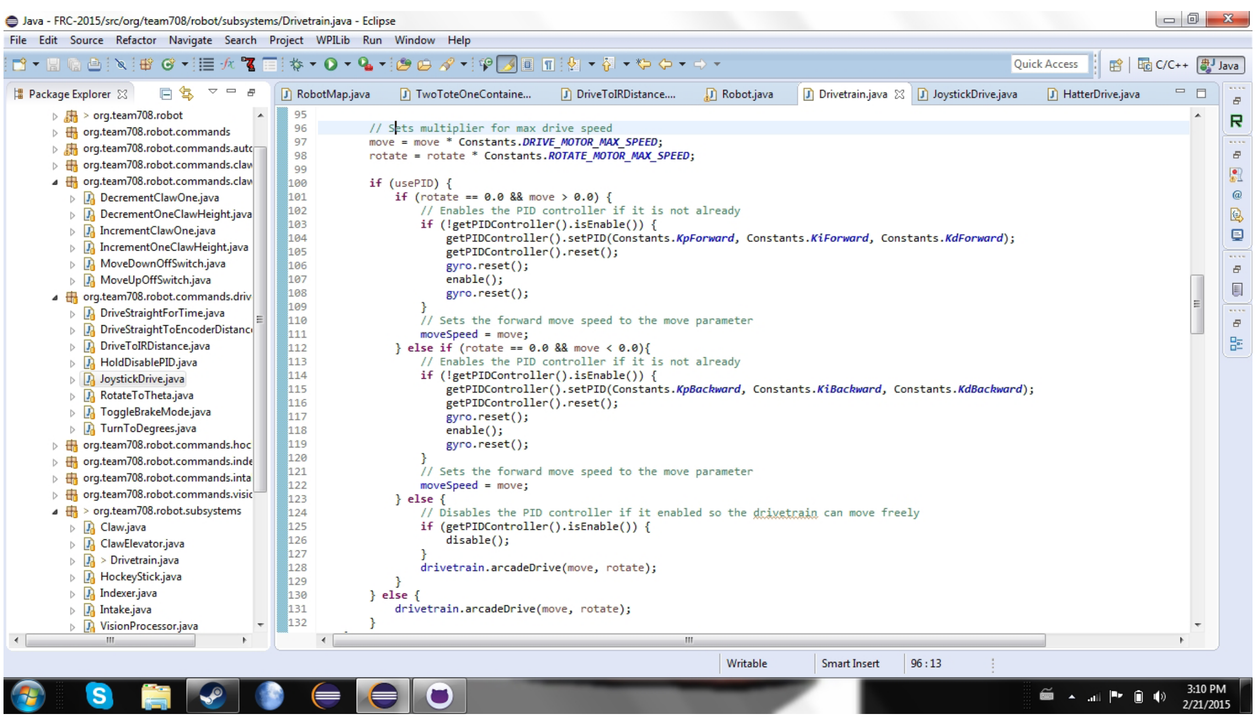




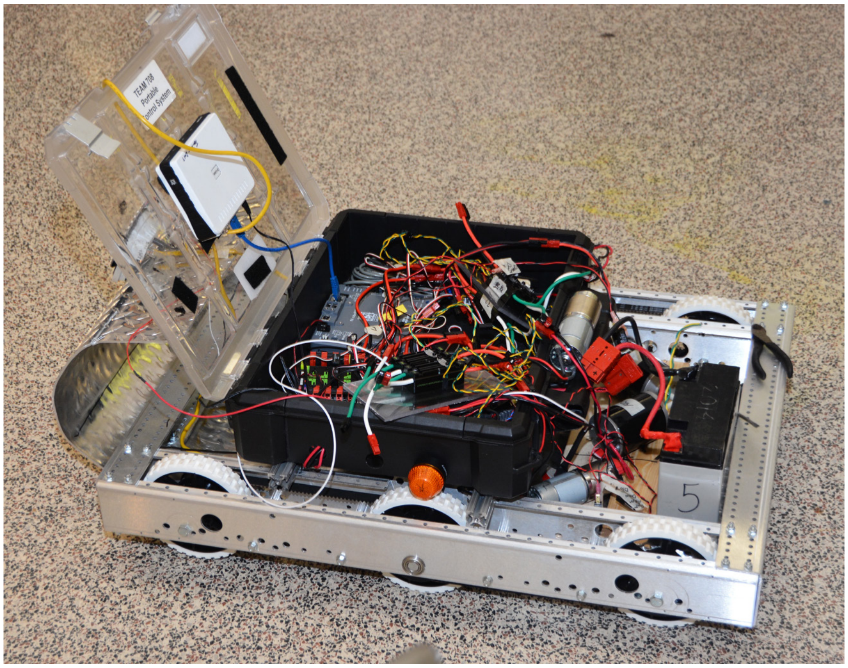


SOFTWARE

The first two weeks of the 2016 season were spent upgrading our RIO, our new Radio, Java and WPI Libraries, and Talon SRXs. In previous years, our Portable Control System, also known as the bombBox, has provided a test bench for any new software written because of its “plug-and-play” construction: motors can easily be added or removed from the box and sensors can be manually triggered by team members. This made the bombBox our team’s first choice for testing the control system and its updates. The first thing we did this year was train all the new members of the software team on Java using code academy and codingbat. We then divided the software into the subsystems defined by the design. After we assigned different members of our software team to the different subsystems. Each team then defined the requirements for each subsystem; what actions the robot needed to perform and what sensors and manipulators needed to be included. These requirements were reviewed by the software team as a whole and then pseudo code was written for each function within the subsystems. When the team was satisfied with this step in the process the actual robot code was written.



We used github as our configuration control system. Each teams software was baselined on a separate branch in github. The bombBox allowed for immediate testing of each subsystem even though this year's robot wasn't fully assembled until week 5.

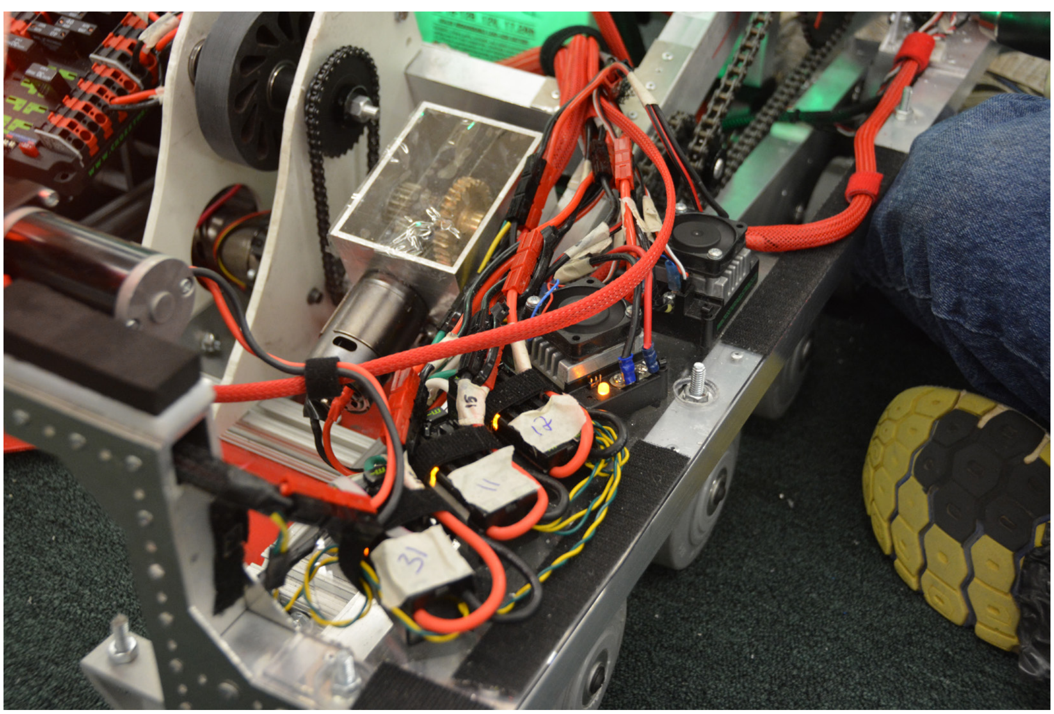


We planned and wrote several different autonomous modes. These modes ranged from simple functions such as moving forward to the defenses, to complex sequences such as crossing the defense and shooting using vision tracking software. The vision tracking software is new this year. It uses roborealm application to identify the target, calculate the target's center, and determine the distance of the robot from the target. The target is centered using the X coordinate passed to the RIO as a pixel point on the screen. The robot moves left or right to center that pixel point within the video, captured from the camera. The robot moves to the correct distance by using the Y coordinate passed to the RIO and shoots.

ELECTRICAL

The brain of the robot can be found in our electronics system. Unlike last year we decided not to use one large board that all the systems could be mounted to. In the very beginning of the season we decided that a more spread out and versatile control systems layout would be more efficient to save space and weight. We looked back at this past years summer robot to see if we could implement the idea of a shelving unit. Originally we wanted small pieces of poly carb to come off some part of the robot vertically. [insert photo] However, our team wanted to make a compact robot to be able to drive under the low bar so we decided to choose a different layout.

We started designing a new layout using a CAD model of the robot, and worked on the two largest electronic systems first: the Robo RIO (RIO) and the Power Distribution Panel (PDP). After a few discussions we decided to add a piece of polycarb to the frame of the robot next to the shooter. There we mounted the PDP. Next we looked at where we could mount the RIO and not have interference with the battery. We also had to keep in mind the our Gyro sensor was connected to



the RIO in the upper right hand corner. We decided to put the RIO in the center of the belly pan on the robot, and have a battery mount a few inches above it. Therefore the wires were easily accessible when the battery was out of the robot. We attached the motor controllers to another two pieces of poly carb along with the radio on either side of the drivetrain. They were connected to the perimeter frame of the robot, and the two pieces were identical. On the right side of the robot on polycarb were three talon SRXs and the Radio, on the left side on polycarb were another three talon SRXs along with two talons. We put the Virtual Control Module (VRM) under the two sims for the right side of the drive train, therefore they would be close to the Robo RIO. Under the sims on the left side of the drivetrain we put two talon SRXs which power the motors for the hanger. Our camera is mounted on the the back of the loader, and has a LED ring around it to detect retro reflective tape for scoring accurate and precise high goals.

We have many sensors on our robot, and they all help the robot function properly. The IR sensor which is placed on a mount on the bottom of the shooter allows us to locate the ball as it comes in from the intake to the loader. We detect the right position the ball should be in for when we power the shooter. We also use encoders for the robot, one to count the rotations on the drivetrain, and another for the rotations on the lead screws when the hanger extends to scale. We use a ¾ potentiometer (pot) to change the angle and pivot in the hanger. We also use limit switches, two on the arm for a hard stop when the hanger extends to scale the tower, and the other for when we bring the arm back down.

For the layout of the wires we decided that we wanted everything to look neat and presentable. We had many ideas for this, one being to run the wires underneath the polycarbonate blocks, or through some of the tubing. We ended up using a chinese finger trap material and fed the wires through that, so therefore the wires were more compact and organized.

TEAM 708

HATTERS

ROBOTICS