# Metal Moose

1391

# Engineering Notebook

2024

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# Kickoff

We spent day 1 watching kickoff and then splitting up into small groups. The main goal for these groups was to analyze the game rules, guidelines, field layout and scoring. After 2 hours we met up again as a team, discussed our findings of the game manual and developed strategic scoring imperatives.

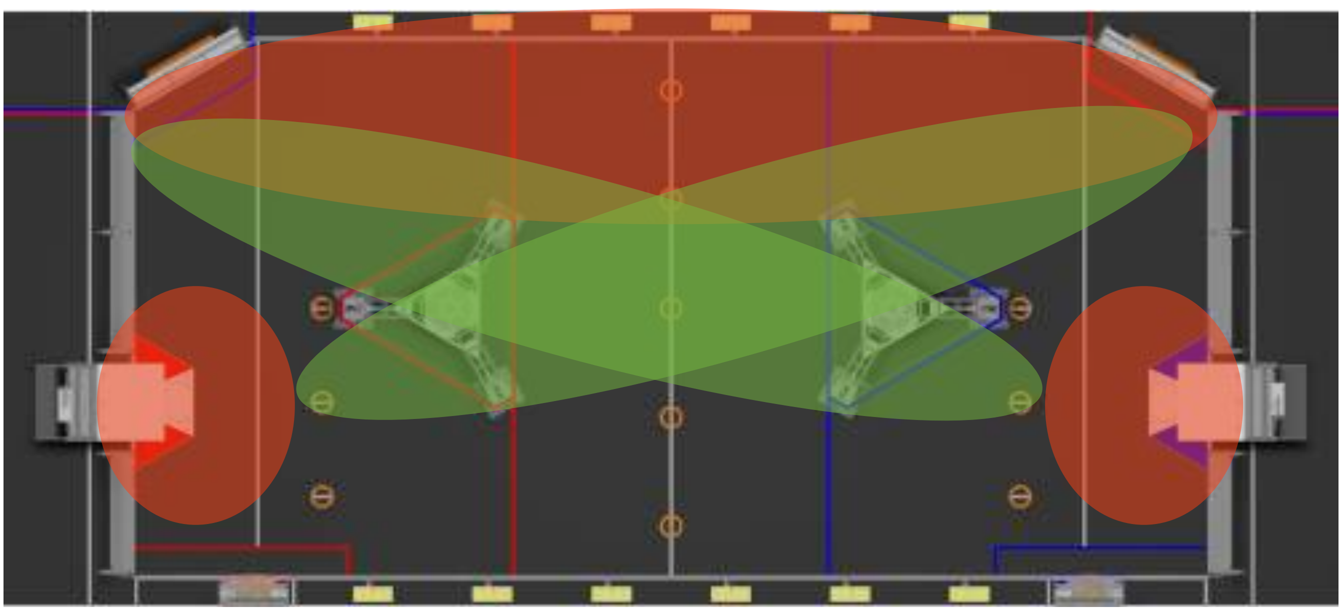
# Game Analysis

**Immediate Goals For Robot:**

- Ground and source intake
- Amp and Speaker Scoring capabilities
- Sub 10 second stage climb
- Able to drive under stage
- Swerve drive base

**Future Goals:**

- Trap scoring
- Shoot into speaker consistently from inside our wing

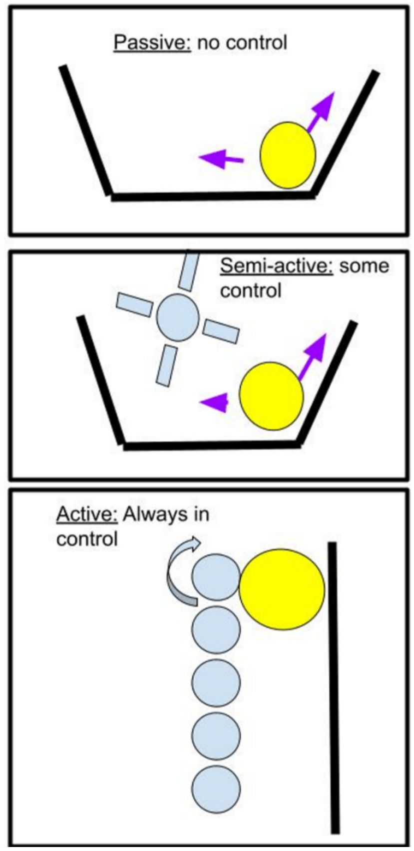


Looking at the field we thought the zones highlighted in Red were going to be very busy, to avoid them we wanted to be able to shoot into the speaker from a distance to avoid traffic. Also fitting under the truss meant we could drive under it rather than getting stuck in traffic by going around. We also thought the source would be very busy so the ground intake meant we could quickly grab a piece and leave without going up close to the source. Our ideal path is shown in Green.

# Intake

**Requirements:**

- Ground intake only (shooter will handle pick up from source)
- Somewhat protected from hits and collisions (Last year's broke a couple times)
- Can pick up note when robot is moving at any speed
- Quick pickup and transfer to shooter
- Active or at least semi-active Intake (consistency and speed)




**Key Decision:**

- Under the bumper or over the bumper intake:

| | Under the bumper | Over the bumper |
|---|---|---|
| Pros | - Less chance of getting damaged<br>- Faster transfer | - Can reach up to 12 inches further out |
| Cons | - Less reach<br>- Less visible pickup<br>- chance of note getting stuck under | - Higher chance of getting damaged |
| Example | <br>Example from team 95 | <br>Example from team 708 |

**Conclusion:** We decided to make a over the bumper intake, mainly for the 12 inches it can reach out over the under the bumper intake. This would be especially useful for autonomous and the race for centerline notes. We also thought we could make the intake durable enough.

# V1 Intake Prototype

For the first version of the intake we used 2x4 wood and hex shaft with drills on the ends to try out picking up notes and find what wheels or belts worked best.


**Pros:**

- Picks up note well

**Cons:**

- Still wood and heavy
- Not sure if note compression is ideal

**Findings:**

- Belts are good to keep note in constant contact and prevent it getting stuck.

# V2 Intake Prototype

This prototype allowed for adjustable note compression to find our ideal intake compression to be 1.5 inches.

**Findings:**

- The belts we were using were not wide enough and reduced how well we picked up notes.
- We needed the same diameter on the shaft all along it so the note would pick up the same.

# V3 Intake

This version was the first one that was modeled in CAD and included motors, new wider polyurethane belts and was mounted to the test bot chassis. Even though it couldn't actuate into the frame perimeter yet it was still useful as a first version. The intake allowed for an adjustable floor height and amount of belts.

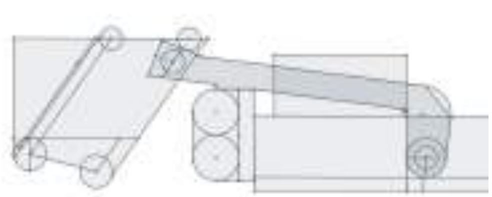
**Findings:**

- More belts meant we could pick up the notes more consistently.
- The top belts should be a little lower to the ground than a note so that it pulls in the note.
- A 35 degree piece of wood inside the intake worked great as a centering guide for the note.

# V4 Intake Prototyping

The intake now had to be movable so it starts in the frame but reaches 12 inches out when collecting notes. We could either do a four bar / virtual four bar or a linear slider. We thought the slider would waste too much room so we decided to try the virtual four bar.

To make sure the virtual four bar intake worked like it did in CAD it was made out of wood and mounted to a cart. This cart was then slammed into a wall and the intake would spring up confirming it worked effectively.



# V5 Intake

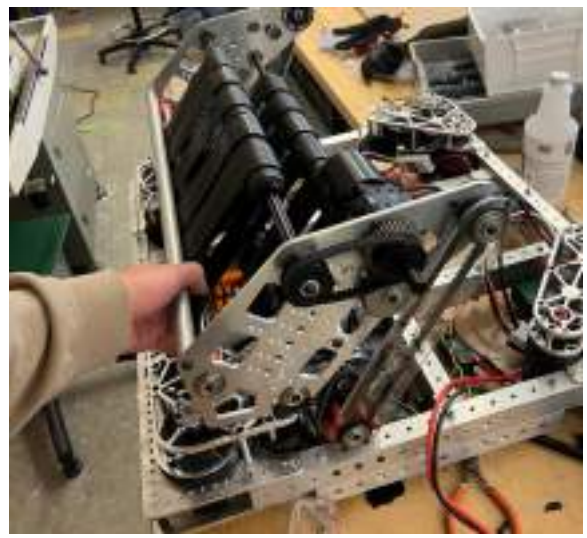
This intake was the first "legal" intake and was modeled in CAD with the first version of the drive base. It consisted of 10 polyurethane belts, 5 on each side being run by a neo. The sides were machined out of 3/16th aluminum and the arms were made out of 1/8 inch polycarbonate. Aluminum tubing was used in between for structural integrity.

**Pros:**

- Moves in and out like it should
- 5 belts pick up note really well

**Cons:**

- Virtual 4 bar was too floppy and wiggly with the 1/8 inch polycarbonate arms
- Floor riding piece was inconvenient and the intake should just have a hard stop



# V6 Intake

Improvements in version:

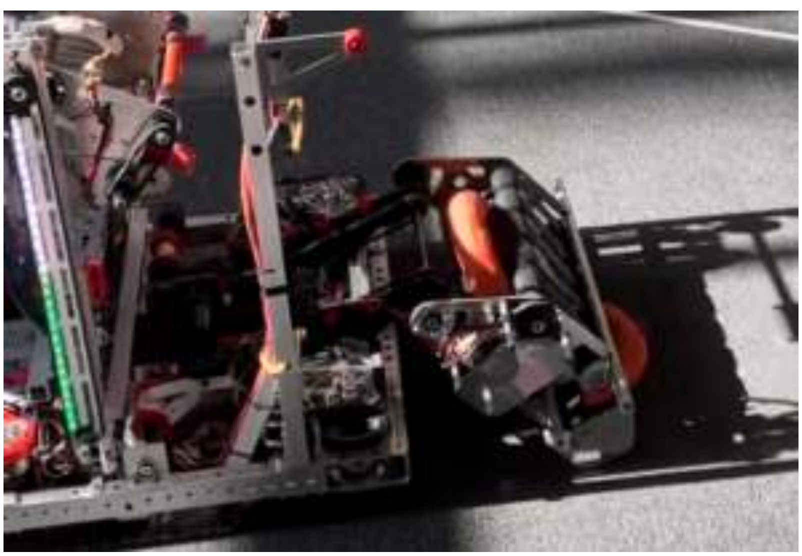
- The polycarbonate arms were moved on the inside of the intake to reduce floppiness.
- Belt drive motor was moved to outside so it wouldn't get in the way of the note.
- Since the new intake was now smaller, side shields were added to help center the note and act as hard stops when pulled up.

# V7 Intake (Final Before comp)

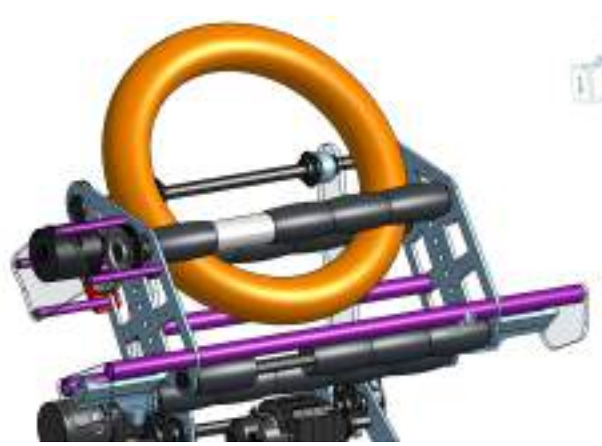
The biggest issue was the floppiness of the intake, so the polycarbonate arms were changed from 1/8 inch to two pieces of 1/8 inch stacked which didn't work great so they eventually became a piece of 1/4 inch polycarbonate on either side. Chain was also used instead of belts to make it stronger and chain turnbuckles allowed for tensioning.

2 x 1/8 inch polycarbonate

1/4 inch polycarbonate with chain & turnbuckle



Intake collecting successfully

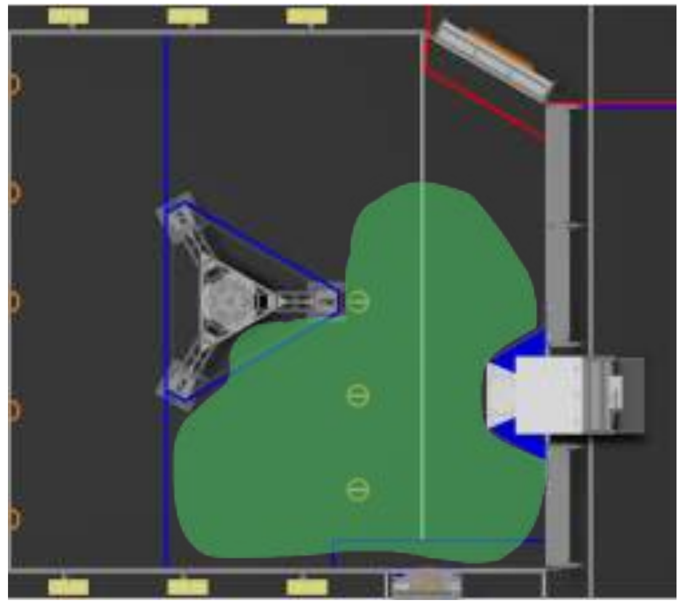


Intake CAD

# Shooter

**Requirements:**

- Shoot at different distances from speaker (ideal shown in green)
- Aim down into amp (with help of elevator)
- Be able to pick up from source (as backup if intake breaks)
- Be able to hold note from intake transfer
- Quickly be able to spit notes (feed for alliance partners)

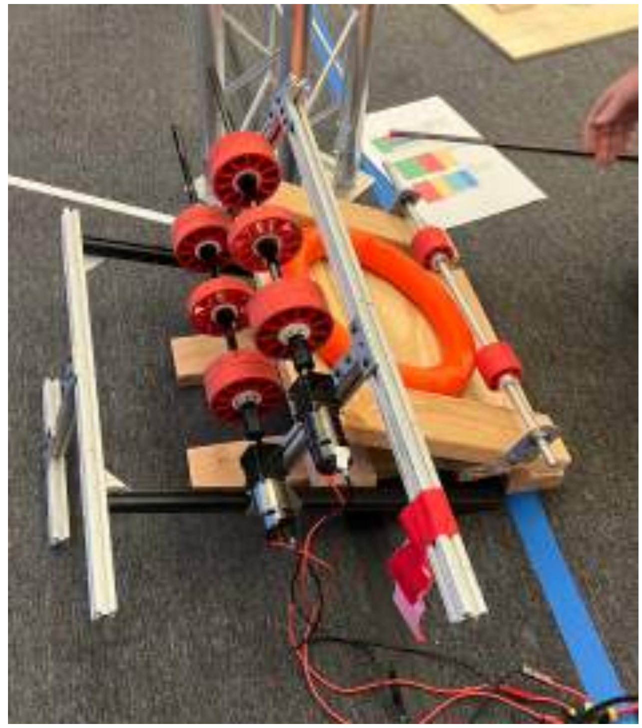


## V1 Shooter Prototype

The first test for the shooter was a couple of 80-20 pieces in a rectangle with flywheels on both sides. The distances were adjustable and we tried different types of wheels. Overall this Proved to be inconsistent and didn't show us much so we wanted to try a more robust version. The note fell in between the fly wheels so we also needed a flat surface for the note to glide on. Squeezing from the sides didn't seem to work so we wanted to try the other way round.

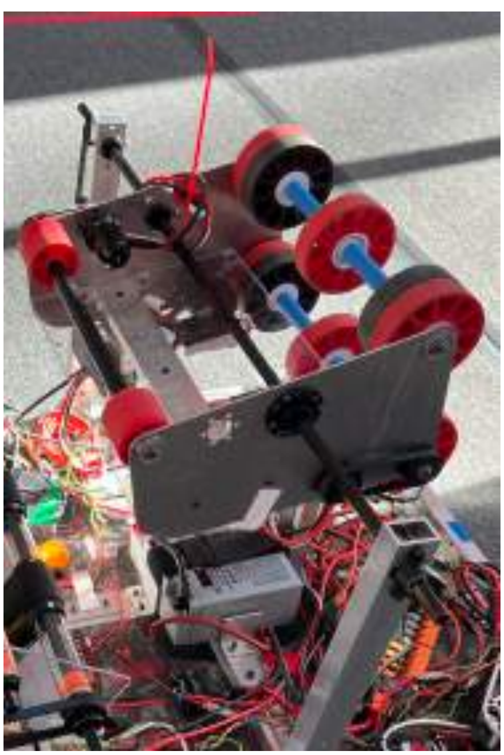
# V2 Shooter Prototype

The second version of the shooter had two rows of shaft with wheels as the shooter part and a loader on the back to feed the note. The note would slide along a piece of plywood and keep straight. The design allowed for adjustable flywheel distance, shooter angle and flywheel speed.



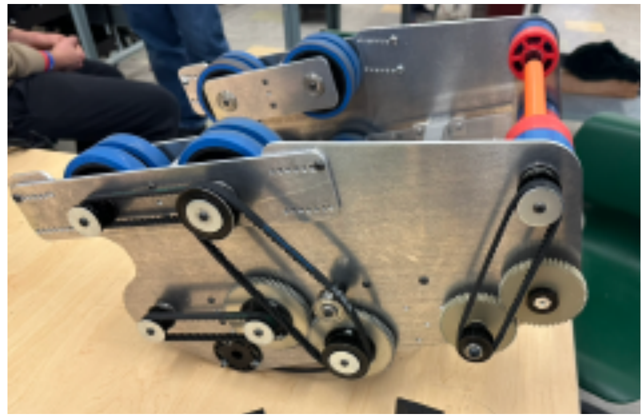
This design seemed way more promising so we tried to make it more robust.

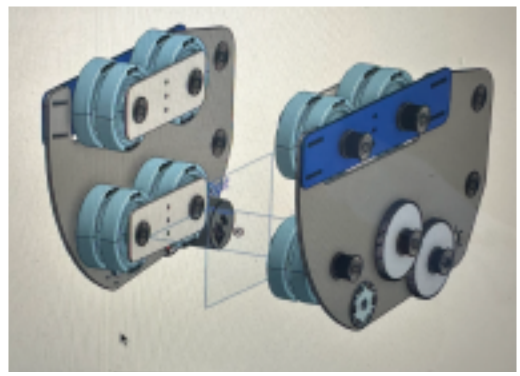
# V3 Shooter



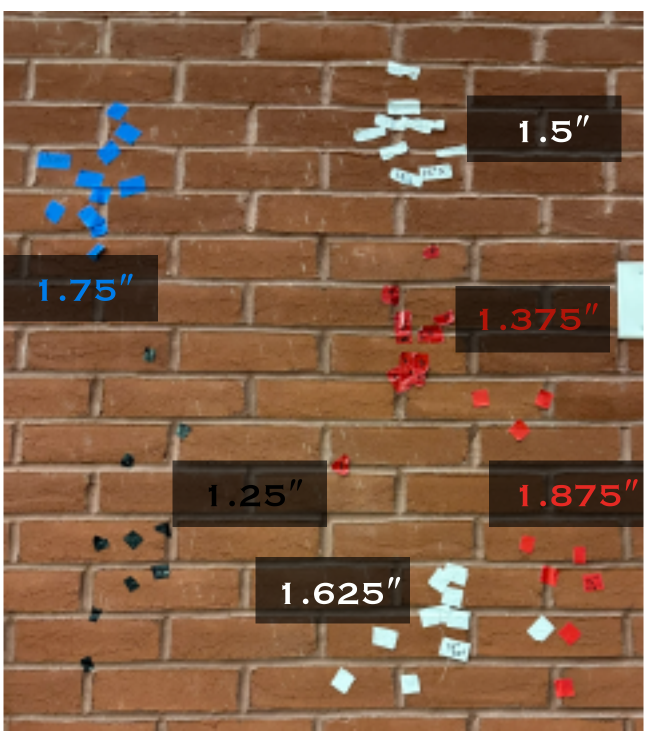
V2 was redesigned, built and mounted to the test robot to try and have something programmers could use. The issue was we still weren't sure what wheels worked best, what compression worked best and other factors so this shooter was useful to a certain extent but we needed an adjustable one to actually make decisions.

# V4 Shooter Prototype





This version was made to try out certain things: The compression distance between the wheels could be adjusted by set holes and changed the distance 1/8th of an inch. Now there were two rows of flywheels and we used a different type of wheel. The second row could be removed if it wasn't useful and the wheels were all tested to see which type was best. Also this shooter now had both sides running independently which allowed for spin on the note which we found to work better.




After shooting at a target with every compression we found the most accurate one was 1.5 inches. Also we realized the pivot of the shooter should be centered and low to keep it balanced and to lower the center of gravity.

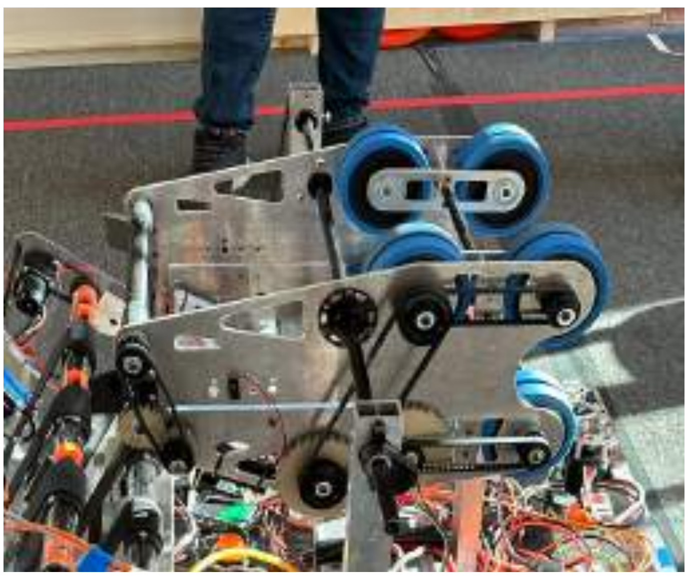
V4 Pivot Location (Unstable)

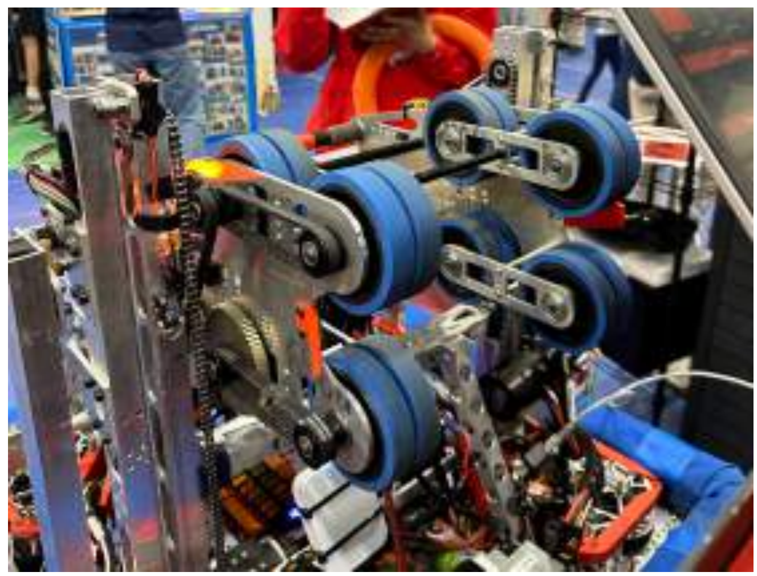
# V5 Shooter

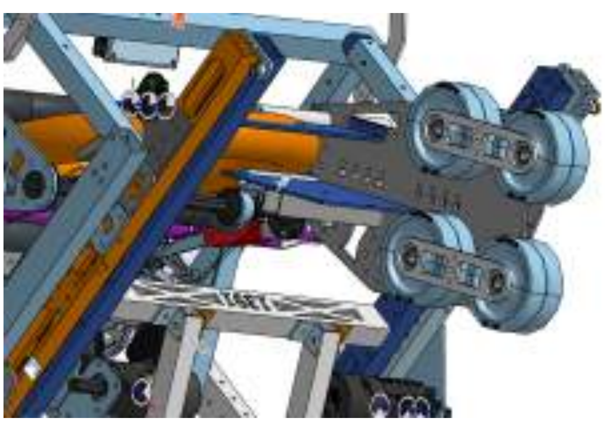
Improvements in version:

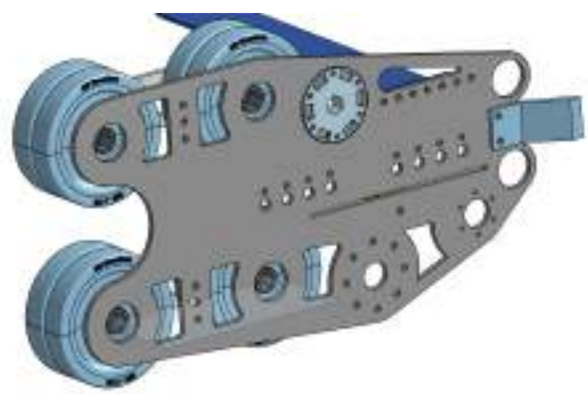
- Finalized compression between wheels
- Lighter, more robust and smaller
- Holes for beam break sensor
- Fins to help align in intake transfer and source feeding
- Different feeder wheels -> roller (More consistent)

# V6 Shooter (Final before comp)









This version was pretty similar to the last but had better belt geometry which meant we got up to speed faster as well as other minor improvements.

# Elevator

**Notes:**

2 Years ago we already made an elevator mechanism and learnt a lot from this. Using what we learned we designed a better version of our 2022 robot elevator.

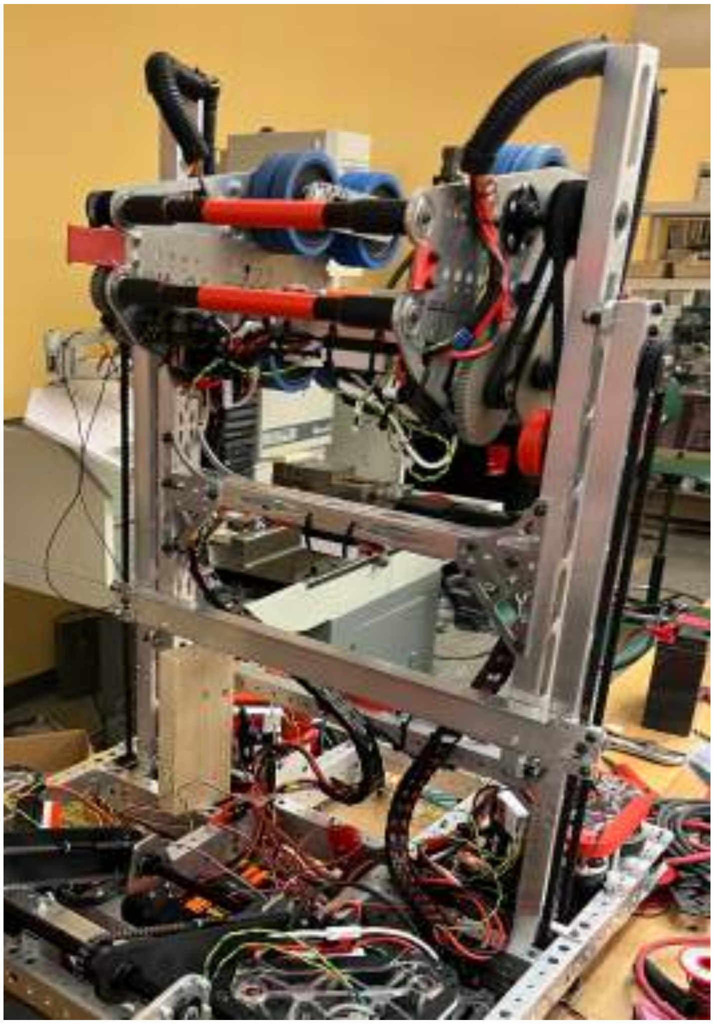
**Requirements:**

- Reach to or almost max height (Useful for amping and especially for trapping in future)
- Take up as little room as possible
- Easy to fix (2 years ago our elevator had belts on the inside and if one were to break it would have taken too long to fix)
- Allow for the shooter to mount to it and pivot on it.

Elevator 2 years ago

**New Elevator**

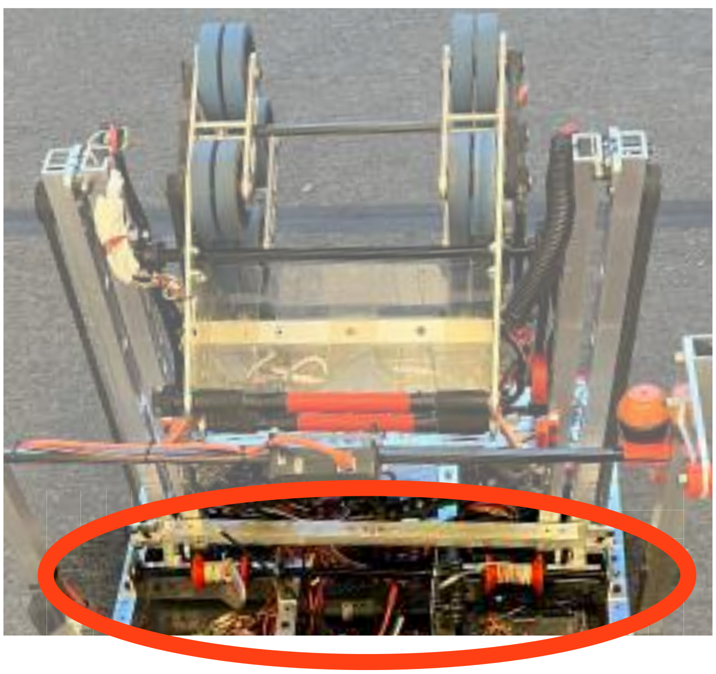
Consisted of two outer rails that stood still and two inner rails that slid up the outer 2 using bearings. A piece of box was put in between to keep the outer rails from bending out. The inner two rails also had a cross piece that held the rails together. The Shooter was mounted on a pivot point held by bearings towards the top of the inner rails with a through bore encoder to find its rotation accurately.



This elevator version clearly had some flaws with the main one being the uprights were bending outwards. We didn't have enough time to fix this before the first competition so we decided to deal with it but thought we would change it before the second competition (and did change it). Apart from the instability due to the elevator being mounted to 1/16 inch box and the uprights bending out, the elevator worked, the shooter could pivot on it and we fit under the stage at our lowest configuration. **The next version of the elevator made after our first event fixed these issues, page 28 shows the new version.**

# Climber

Our original idea for the climber was quite simple. Two hooks tied to a string would be spooled at the base of the robot using a ratcheting gearbox. These hooks would be attached to the elevator during the match and when climbing the elevator would bring the hooks over the chain and then once we began spooling the hooks would detach from the elevator and pull us off the ground.

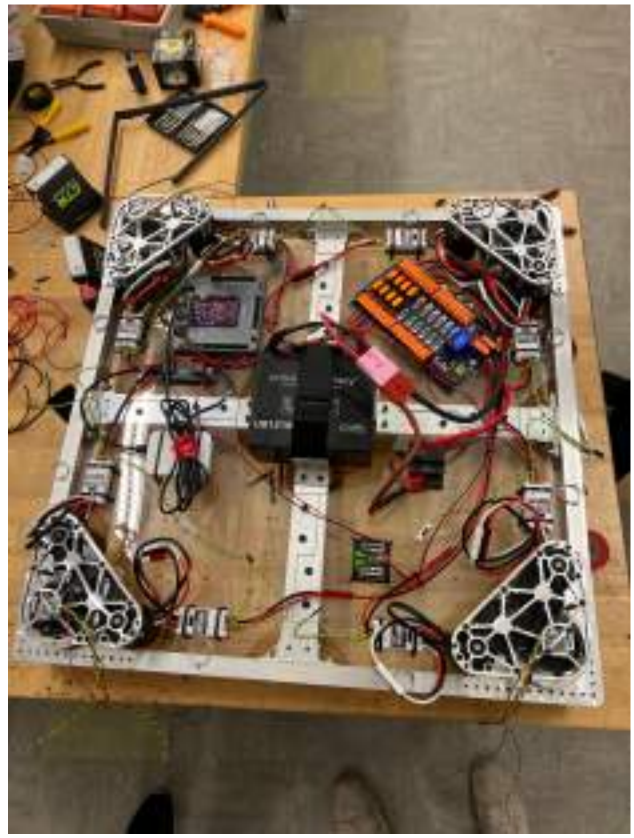


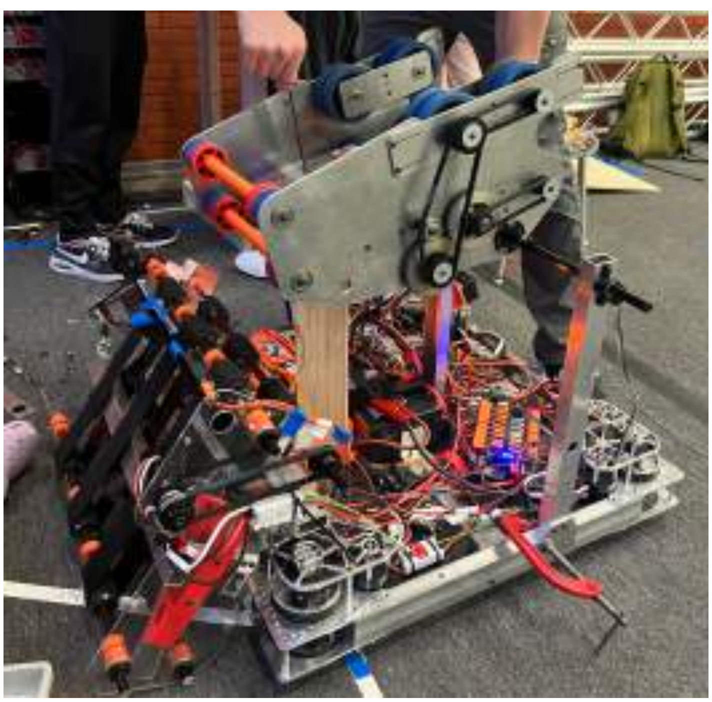
This design worked but was extremely unreliable and we couldn't melody climb due to its instability. The hooks would fall before climbing, the string meant the robot would tip on its side and the shooter had to rotate to get out of the way of the chain which didn't always work. We didn't have the time to redesign this so we used it for the first competition but we knew we had to change the design for the second competition. **A new climbing mechanism was created after our first event and it worked great, page 28 shows this new version.**

# Drive Base

This test bot was created two years ago and served as a chassis to try out prototypes until we decided on the chassis. Also it allowed us to try new versions of prototypes without taking the robot away from programming. The chassis was made from box as the rails supporting the swerve modules and polycarbonate pieces to support the electronics.

Test Bot





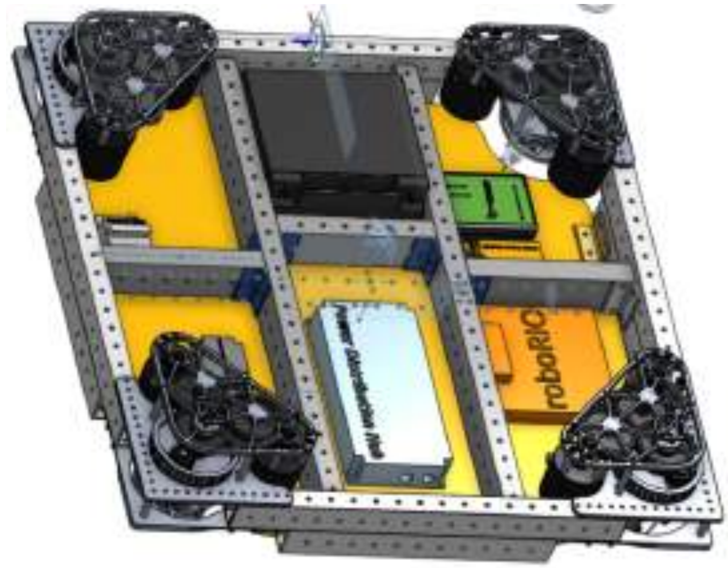
Test Bot being used to try different versions of shooter and intake

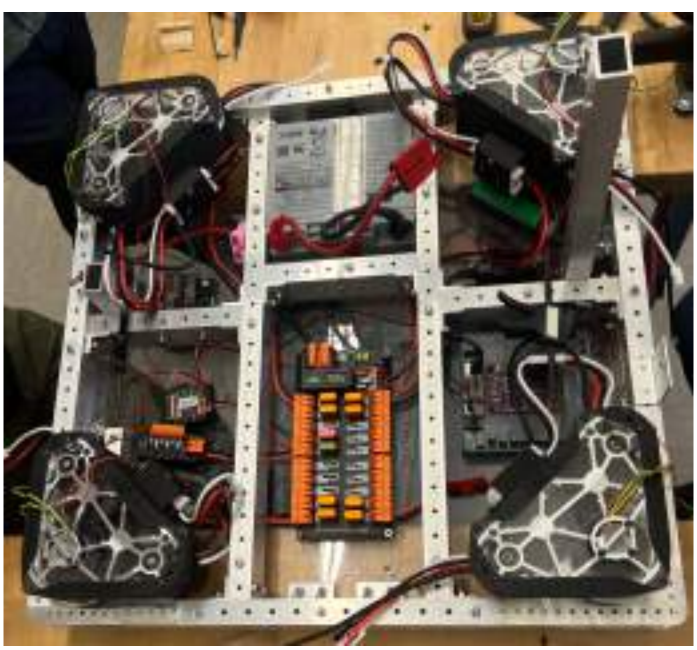
The test bot was also useful because we could drill holes anywhere in the frame and clamp pieces on. And once we knew where we needed mounting holes we could do this on the real drive base. A good thing we learned from the Test Bot is the drive base (or at least bumpers) should sit lower to the ground to prevent notes getting stuck under the robot.

# 26" x 26" Drive Base V1

We decided the drive base should be 26x26 inches to be as small as possible but still allowing for the electronics and subsystems to fit. We knew we were going to use swerve because it made sense for maneuverability and had been extremely reliable last year. We also made the following choices / Requirements:

- Frame as low to ground as possible (Prevents notes getting stuck under and lowers COG)
- Layout electronics



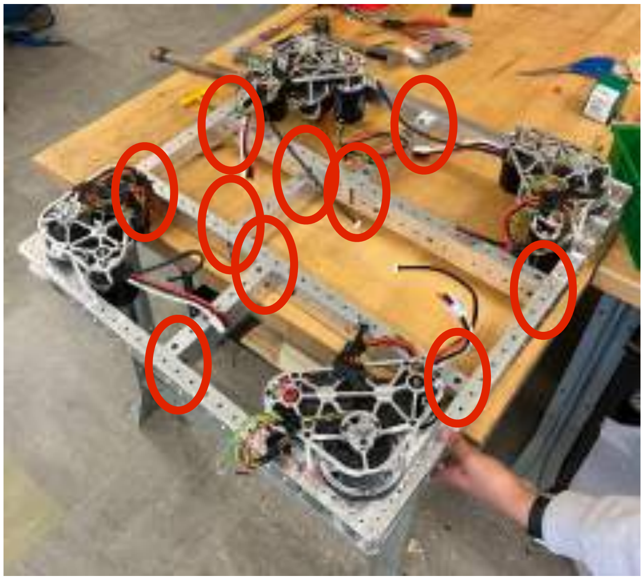



On the outside we stacked two pieces of 1.5" box to allow the swerves to still sandwich and not be too low to the ground but then have the second piece of box lower to the ground so the belly pan could be as low as possible. Then we made the inner rails 2" box so we had 1" of room under the box on the inside for wires to go under and not get in the way of any mechanical parts. We put holes anywhere we could so we could easily mount to the frame.

**Cons (Fixed Next Version):**

- Too heavy
- Angle pieces holding box together gets in the way and is annoying.

# 26" x 26" Drive Base V2

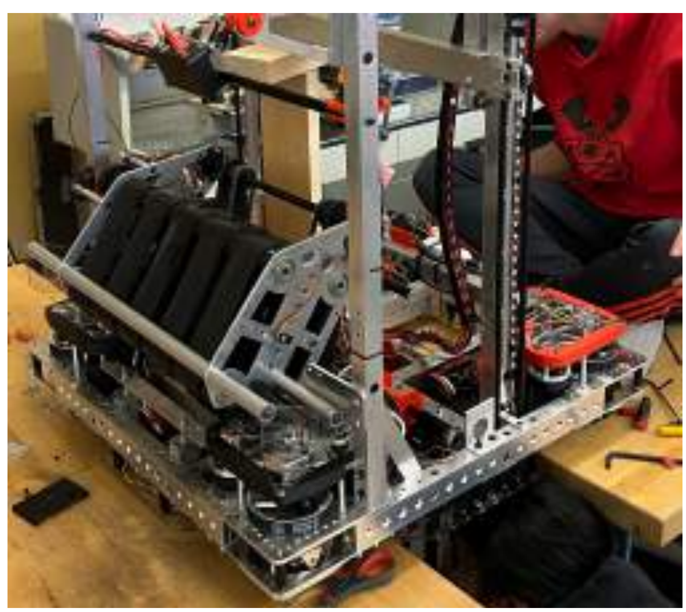


We used the first drive base for 2 weeks and once we were somewhat done with the intake, shooter and elevator we redesigned the drive base focusing on the issues found above. To solve the weight issue, the inner box was replaced with 1/16th inch box and the outer bottom box was replaced by spacers that held the belly pan low. To get rid of the angle brackets we discovered end caps that would sit inside the box and made it really easy to screw box with other pieces. We used these anywhere we could in the drive base.

End Cap

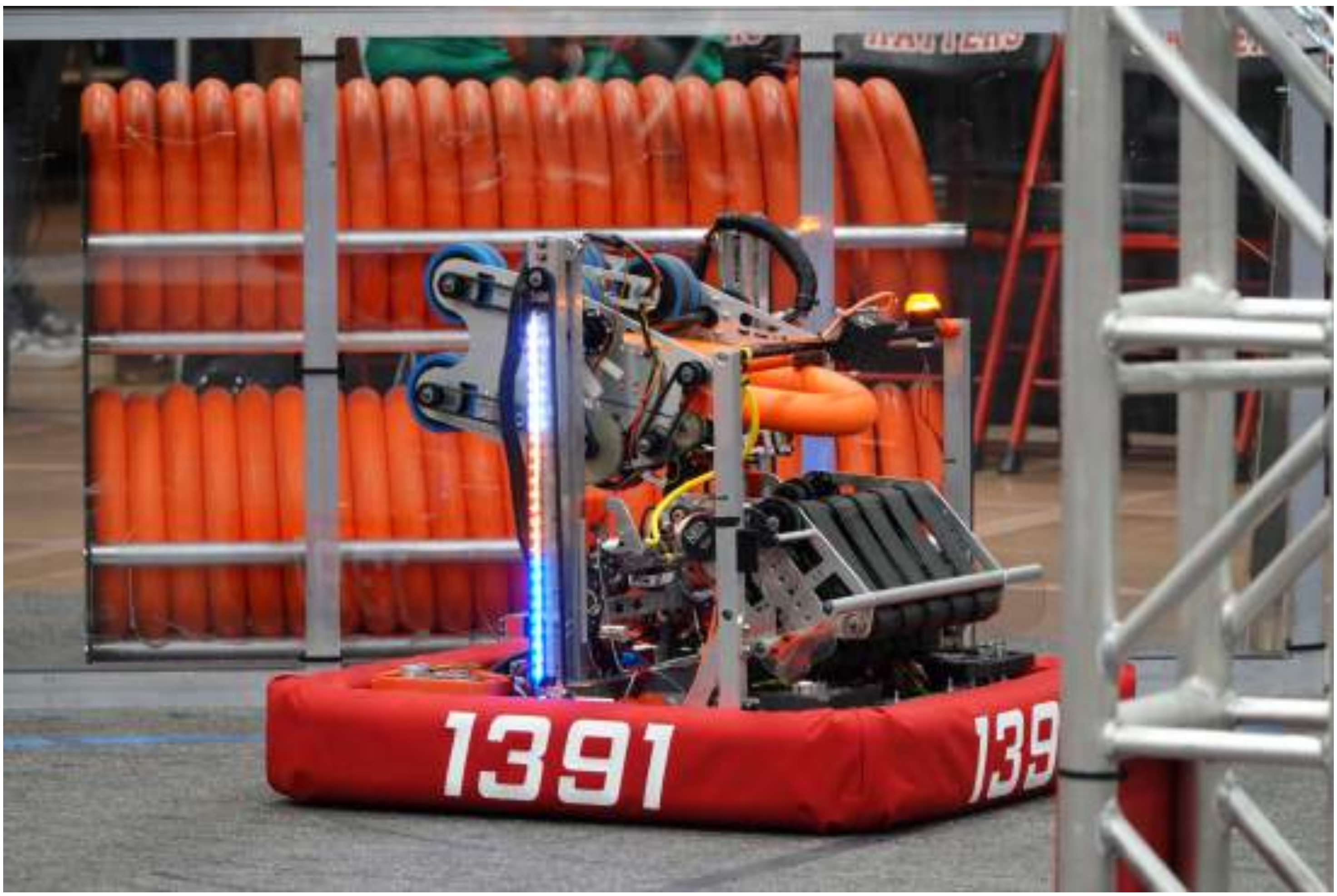
## Conclusion

This drive base worked really well, it was lightweight, strong, had good mounting locations for electronics and did its job. We faced a couple of issues in the first competition that were later solved this Can be seen on on page 27.



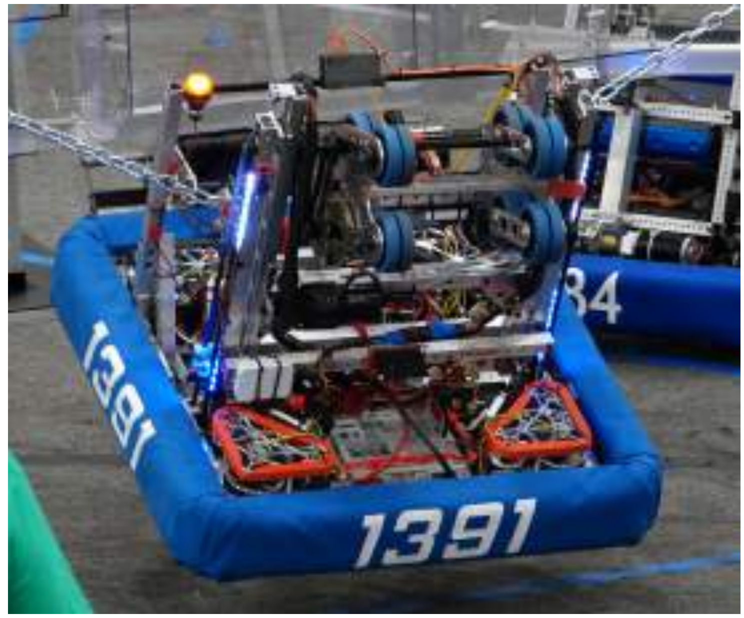
# Team 1391's robot:

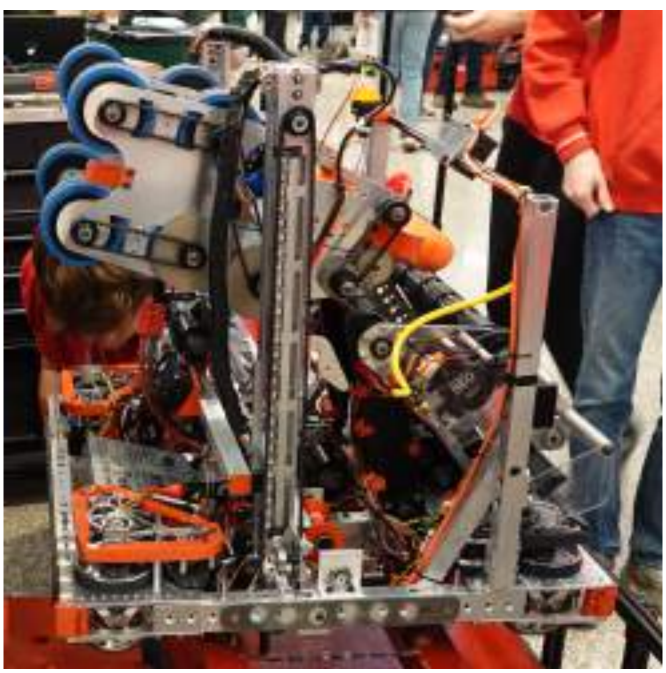
# CLIO



# Robot Final Build

Once the robot components had been put together all that was left were finishing touches. We 3D printed mounts for the radio & camera. Additionally, we made swerve covers to protect the swerve and to mount the swerve's motor controllers because of a lack of space on the electronics board.



LEDs were also added on both sides to signal key things to the drive team like if we have a note, if an April tag is in vision... Lastly, an upright was added above the intake to serve as a hard stop for the intake being up but also to hold the Limelight and RSL. This Limelight is used to track and pick up notes with the intake. Bumpers were mounted using wing nuts on screws that kept the bumper down on the robot.

# Build Evaluation

### What went right:

- We could quickly and effectively pick up notes from ground and if needed from the source.



- Shooting notes worked great when we were aimed right at the speaker and we can shoot from pretty far away. Using set points worked best but automatically aiming worked sometimes.

- The decision to use swerve was definitely the right one. Not only was swerve less of a hassle in both drive base construction and repair, but also it allowed moving around the field to be way easier. The advantage of swerve was especially seen when going under the stage to avoid traffic and quickly cycle notes to our side.

## What went wrong with design:

- The first design of elevator was bending outward and forwards and backwards which meant the shooter wouldn't always stay in the same place. This meant we had a reliable shooter on a wonky elevator so we weren't very good at shooting notes from far. (This was later solved with the second version of the elevator)

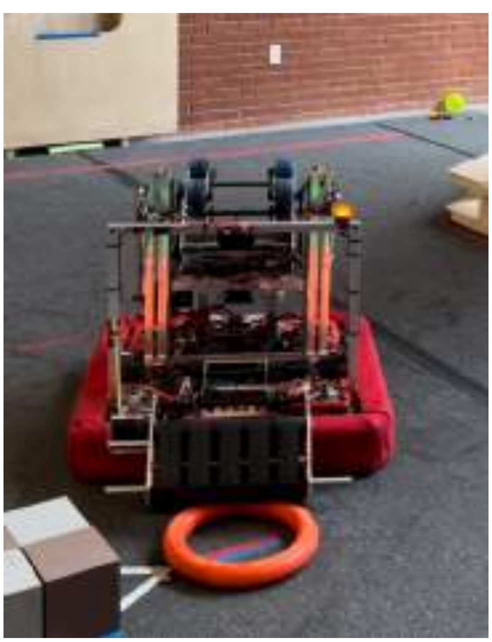

- Programming was not given enough time to work on the robot so we had only one autonomous that was very inconsistent for the competition. (Solved after second competition)


- We couldn't amp because elevator wouldn't go high enough (solved after second competition)

# Week 1 & 3 Event Evaluation

**What went wrong Overall:**

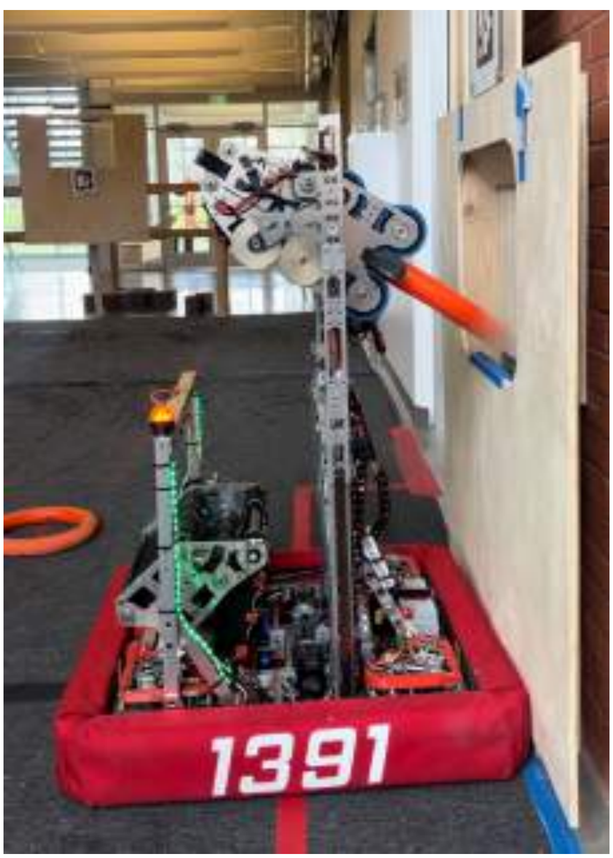
- The Elevator was mounted to 1/16 inch box so it was extremely wobbly and was bending outwards too. This made shooting incredibly inconsistent.
- Climbing was extremely inconsistent as well with the hooks falling out, the climbing sequence being complicated and the winch sometimes not working.
- Drive team really only had 1 day of practice which meant they weren't familiar with how to smoothly control the robot.

- The shooter was pivoting on a belt which left too much slack which resulted in more inconsistent shooting.
- Shooting using the limelight distance was not well tuned so it didn't work.
- We only had one autonomous and it was very bad and inconsistent.
- Still couldn't amp consistently.

## Changes for District event:

**Elevator:** The elevator was way too unsteady so it was completely redesigned. In the last version the elevator had fixed sides and the inside rails moved up, the new version was the other way around. The outside rails now moved and the inside ones held the elevator. Also, the elevator was supported on the inside with a cross piece and that cross piece was supported on the frame to make sure it wouldn't move anymore. The 1/16th inch box on the frame was removed where the elevator was mounted and replaced with C-Channel. Additionally, before it was using belts to move the elevator but this was changed to chain which allowed for better tensioning and prevented the belt from breaking which happened to us. The turnbuckle was later removed from the chain which allowed us to reach higher up and therefore successfully amp.




**Shooter:** The shooter rotation belt was replaced with chain with a turnbuckle to make sure it was always tensioned. Also, with the new version of the elevator the shooter didn't fit perfectly inside of it so a new version of the shooter was attempted that used a double sided belt to avoid using gears but after lots of versions it wasn't working so instead the old shooter was redesigned to take up less vertical space and fit comfortably inside the elevator.

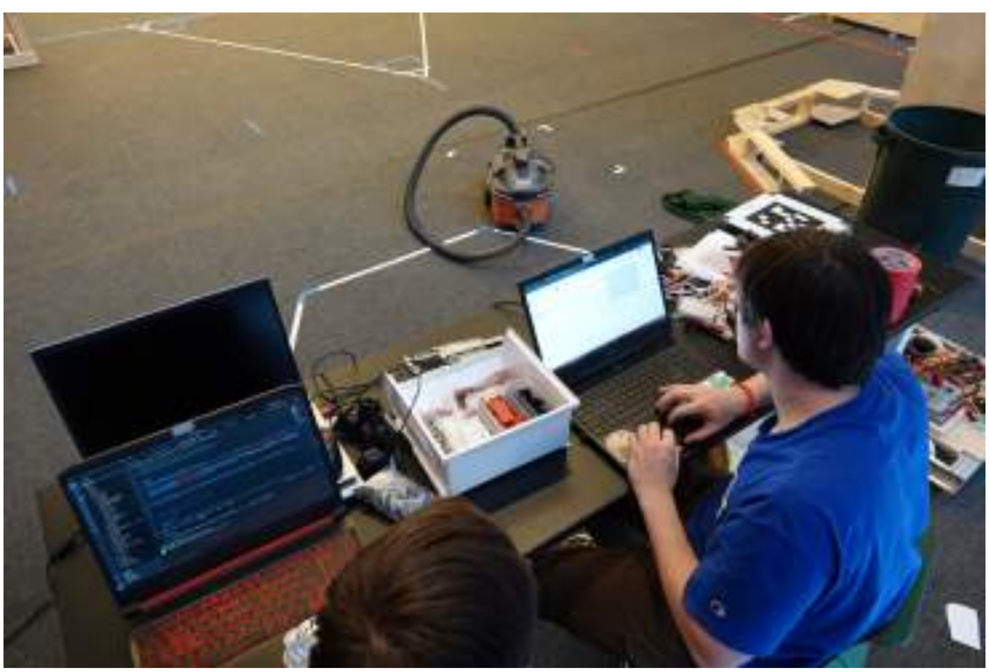
**Drive Base:** Since the 1/16th inch box cross pieces were removed to make The elevator more sturdy, tubing was put in between the frame to maintain its structural integrity.

**Intake:** The intake drive motor to move it up and down was mounted on a piece of C channel above the intake which blocked the PDH and was also bending throughout the competition. This motor was therefore moved to the side to avoid this issue. The plate that held the motor was combined with the plate that held the 4bar axis to prevent the plate from bending in and breaking the chain like it did in our second competition. The gearbox was also having issues due to it having too high of a gear ratio and therefore destroying its own gears. To solve this a MAXplanetary gearbox was used instead which supports higher ratios.

# Programming

This year, the programming sub-team started our pre-competition season by learning the basics of robot programming in Java from returning team members, using last year's robot to try out their code and get real feedback. Also during the preseason, we worked on establishing pose estimation using a limelight and the new AprilTag size for this year.

After kickoff, our highest priorities were to use the swerve robot from last year to establish automatic aiming for shooting in the speaker. The first iteration of this was accomplished by only using the robot's odometry and trigonometry to calculate the exact angle it would need to turn to in order to face the speaker. With our initial testing on our half field, it appeared to be working flawlessly, so we moved on to automatic pathfinding on the field again using the AprilTag-based odometry. Using PathPlannerLib's integrated pathfinder, we established exciting pathfinding we could use to line up with the amp and stage with a couple of inches of error.



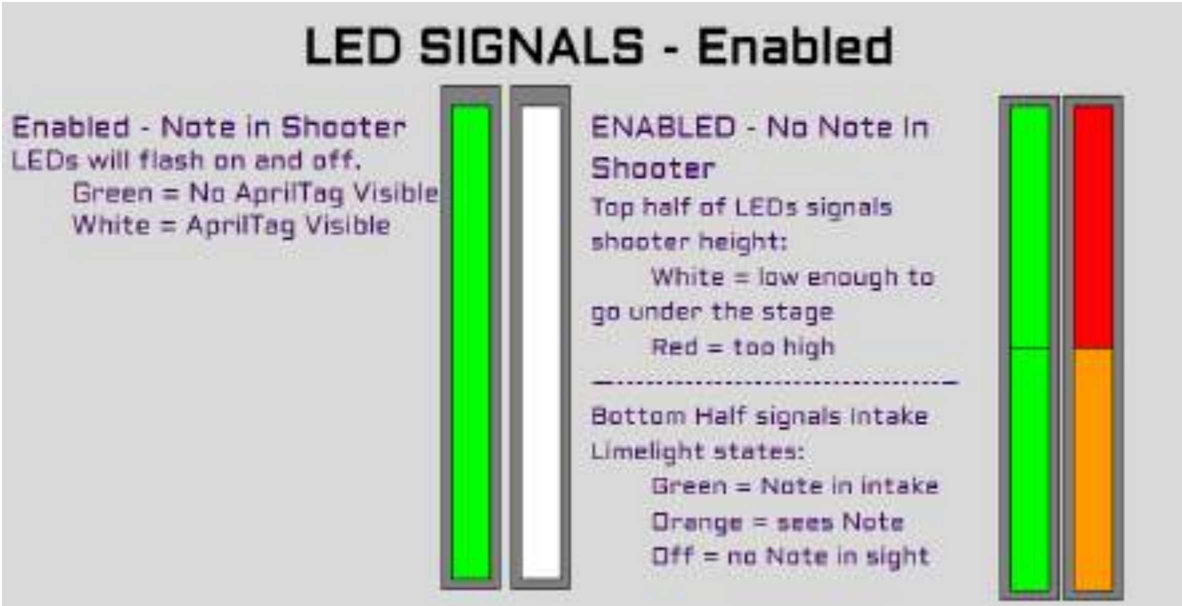
After establishing that code, we decided to try and figure out how we could shoot while moving. After a couple of hours of messing with related rates, we decided to use kinematics equations to create an easily adjustable shooting function to find the angle and change in angle required to shoot a note directly into the speaker from a given distance away and a constant velocity of the robot. Once the first test chassis was ready, we tuned the functionality of it so that we could start testing everything while being able to control game pieces.

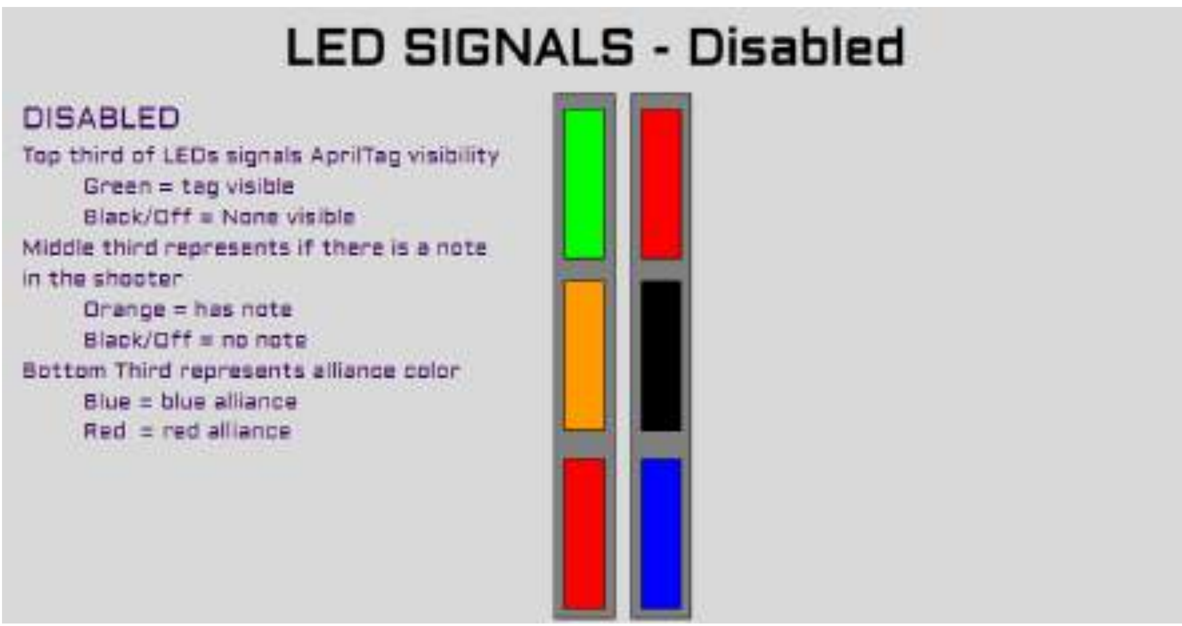
Once the intake and shooter were functional, we moved on to add color and distance sensors to the intake and shooter so that we could automatically sense notes in the robot and automatically position them in the robot correctly. After some testing, we found that a simpler and faster solution was to use infrared beam break sensors, which were smaller and more reliable for our design.

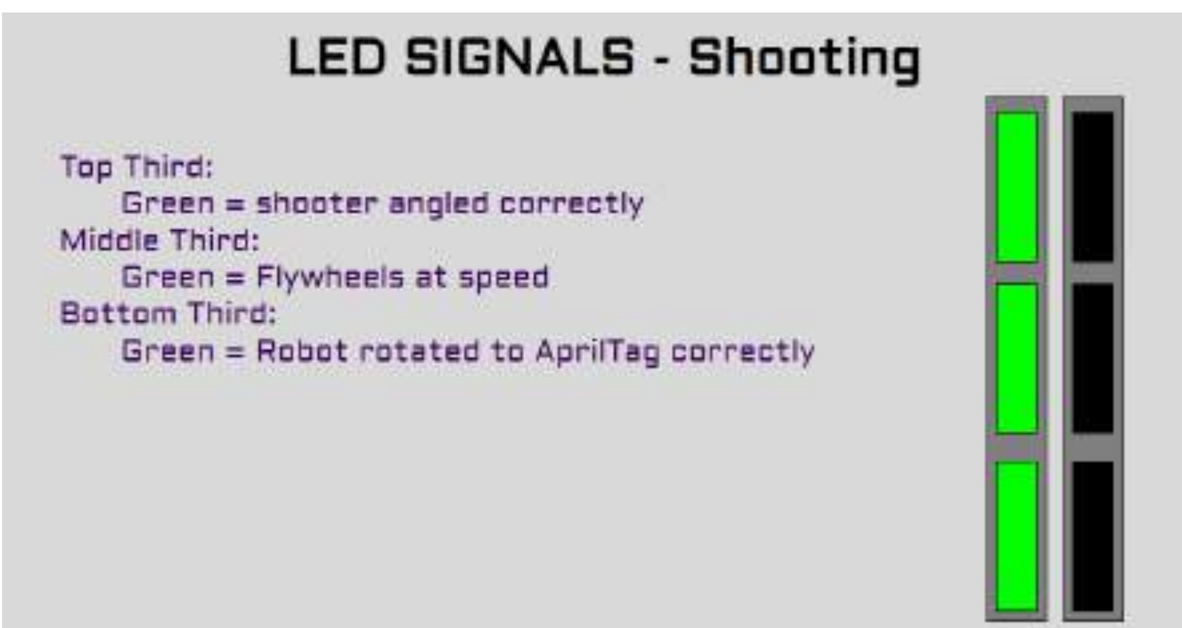
Next, we mounted a Limelight to the front of the robot above the intake so we could track notes and automatically collect them. To detect the notes we tuned the limelight to filter its feed for the specific orange color of the notes. After getting that figured out, we used the TX (x-offset from the center of the camera feed) value returned by the limelight to rotate the robot to center the note in the intake as well as using the TY (y-offset from the center of the camera feed) value to slow down as we approach the note to make collection as consistent as possible.

In addition to the Limelight on the front, we mounted one to the back to be used for shot aiming and field localization. With this, we created a shooting polynomial function based on values we found through trial and error.

Now with a functional robot, we began work on autonomous, creating paths using PathPlanner to define a 3-note autonomous before the build sub-team was ready to upgrade the robot to a more robust and fleshed-out version. While the majority of the robot was unavailable for testing, we created code to control two sets of LEDs on the robot for signaling, as well as detailed documentation of what different patterns mean.


LED SIGNALS - Enabled
Enabled - Note in Shooter
LEDs will flash on and off.
Green = No AprilTag Visible
White = AprilTag Visible
ENABLED - No Note In Shooter
Top half of LEDs signals shooter height:
White = low enough to go under the stage
Red = too high
Bottom Half signals intake Limelight states:
Green = Note in intake
Orange = sees Note
Off = no Note in sight


LED SIGNALS - Disabled
DISABLED
Top third of LEDs signals AprilTag visibility
Green = tag visible
Black/Off = None visible
Middle third represents if there is a note in the shooter
Orange = has note
Black/Off = no note
Bottom Third represents alliance color
Blue = blue alliance
Red = red alliance


LED SIGNALS - Shooting
Top Third:
Green = shooter angled correctly
Middle Third:
Green = Flywheels at speed
Bottom Third:
Green = Robot rotated to AprilTag correctly

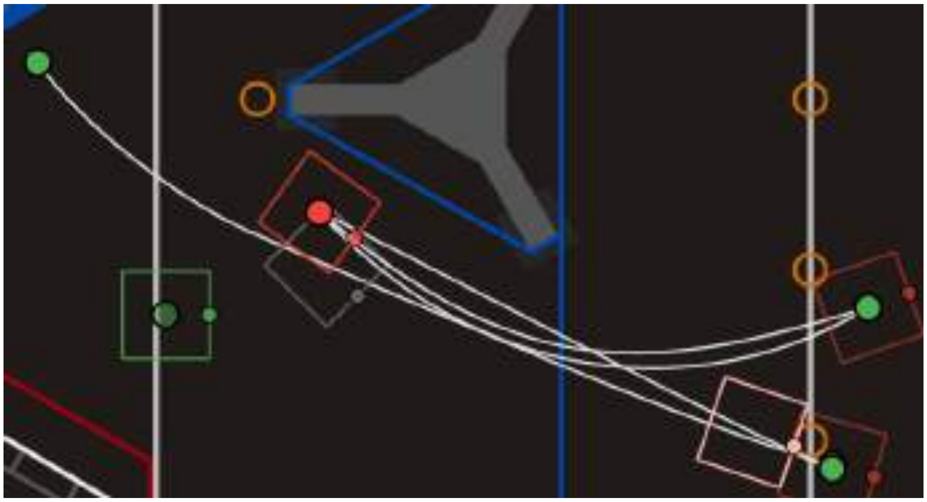
After getting the robot back, we were a couple of days out from our first competition, and we first tuned everything to make it work, as well as implemented automatic buttons for the drivers to use to score in the amp and speaker as well as climb and automatically collect notes. As a backup, we gave the drivers buttons to shoot from against the subwoofer as well as intake from the source through the shooter in the case that the intake or the shooting was off.

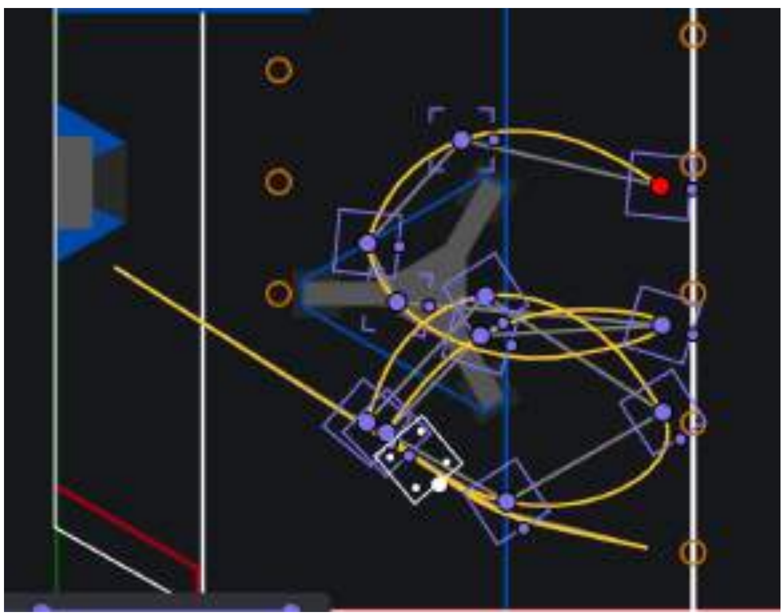
Quickly, we found out that there was something wrong with the odometry when on the full field, as we found out through our shots aiming in the wrong direction and the pathfinding going awry. As our last resort, we reverted to shooting from the subwoofer, a consistent method of shooting.

After the competition, we rushed to work on completely reworking the shooting function, ignoring our odometry and instead using the live readings of the AprilTag's position relative to the robot to get the distance and rotation for the robot, a much more reliable way of aiming. After some testing, we also decided to use a table of values and interpolate between them to tune our shots instead of a continuous function that would be much more challenging to adjust on the practice field. We also created buttons for the drivers to automatically climb, one to raise the elevator and one to lower it.

After a much smoother second competition we decided to try out Choreo, an alternative to PathPlanner for creating paths that calculates the fastest path given certain parameters like robot weight, size, motors, and the positions you want the robot to go to. With a little bit of experimentation, we found that Choreo calculated sweeping motions to be much faster than the paths we were previously using that traveled, stopped, and then reversed direction.

## PathPlanner Paths vs Choreo Paths





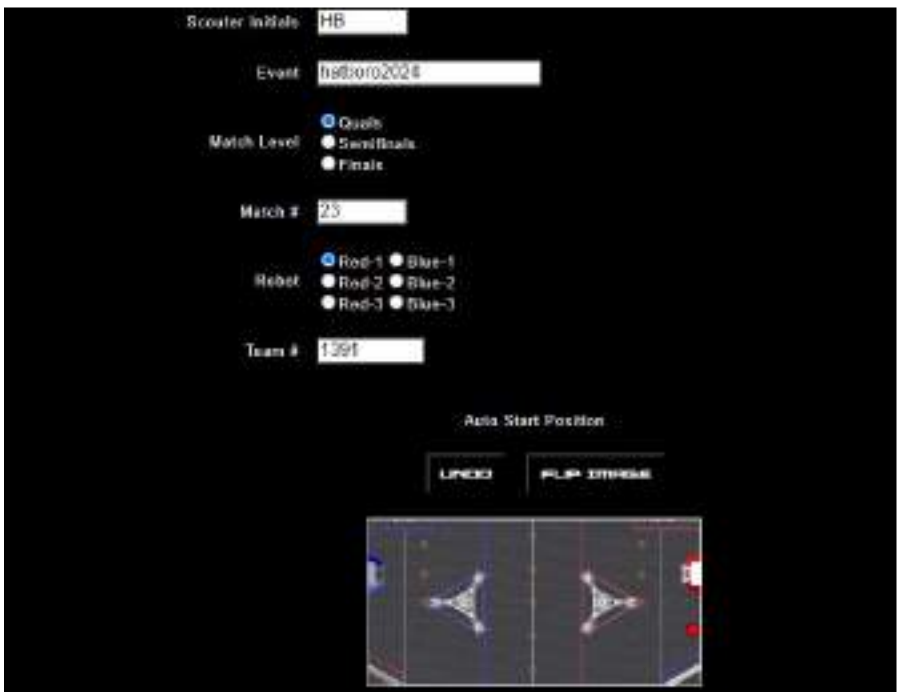
Using Choreo, we created a series of autonomous routines to score 4+ notes starting from each side of the subwoofer as well as one to start near the amp and drive around the close notes, allowing our teammate to run a 4 note auto close while we go straight to the center line while leaving room for a teammate to go to the center line on the other side.

# Scouting

This year, the Scouting team aimed to implement a stable and reusable system for our current and future competitions. We used PWNAGERobotics's scouting system, which offered a configurable template representing the data we wanted to collect. With their system also came the opportunity to utilize the fast reliable QR scanning method of transporting data, so we prepared our devices for an easy scan process. Once the scouting template was configured to our image we focused on having an analysis sheet that could collect data and offer multiple facets of analysis. For this, we used Fondy Fire's analysis spreadsheet, and it has worked ideally for our needs.

We also restructured our protocol system so that during competitions scouting can operate smoothly. We have received more than a dozen laptops from the Westtown Tech Office so that our previous charging issues and computer glitches are no longer a hassle. Scouters can easily collect data from the competition and put it on the given laptops to form a preliminary raw data sheet. The data is sorted into a QR code and scanned to be put on the master computer, which organizes the data so that it can be entered into the pit computer. We replenish the pit computer with data around 5 matches before our team's match.


CRESCENDO
GENERATE QR CODE


Scouter Initials
HB
Event
hatboro2024
Match Level
Quals
SemiFinals
Finals
Match #
23
Robot
Red-1
Blue-1
Red-2
Blue-2
Red-3
Blue-3
Team #
1391
Auto Start Position
UNDO
FLIP IMAGE


CRESCENDO
ENDGAME
PREV
NEXT
Notes Scored in Trap
Stage Timer
Start
0
Reset
I Messed Up The Timer
Final Status
Parked
Harmony
Not attempted
PREV
NEXT

# Thank You