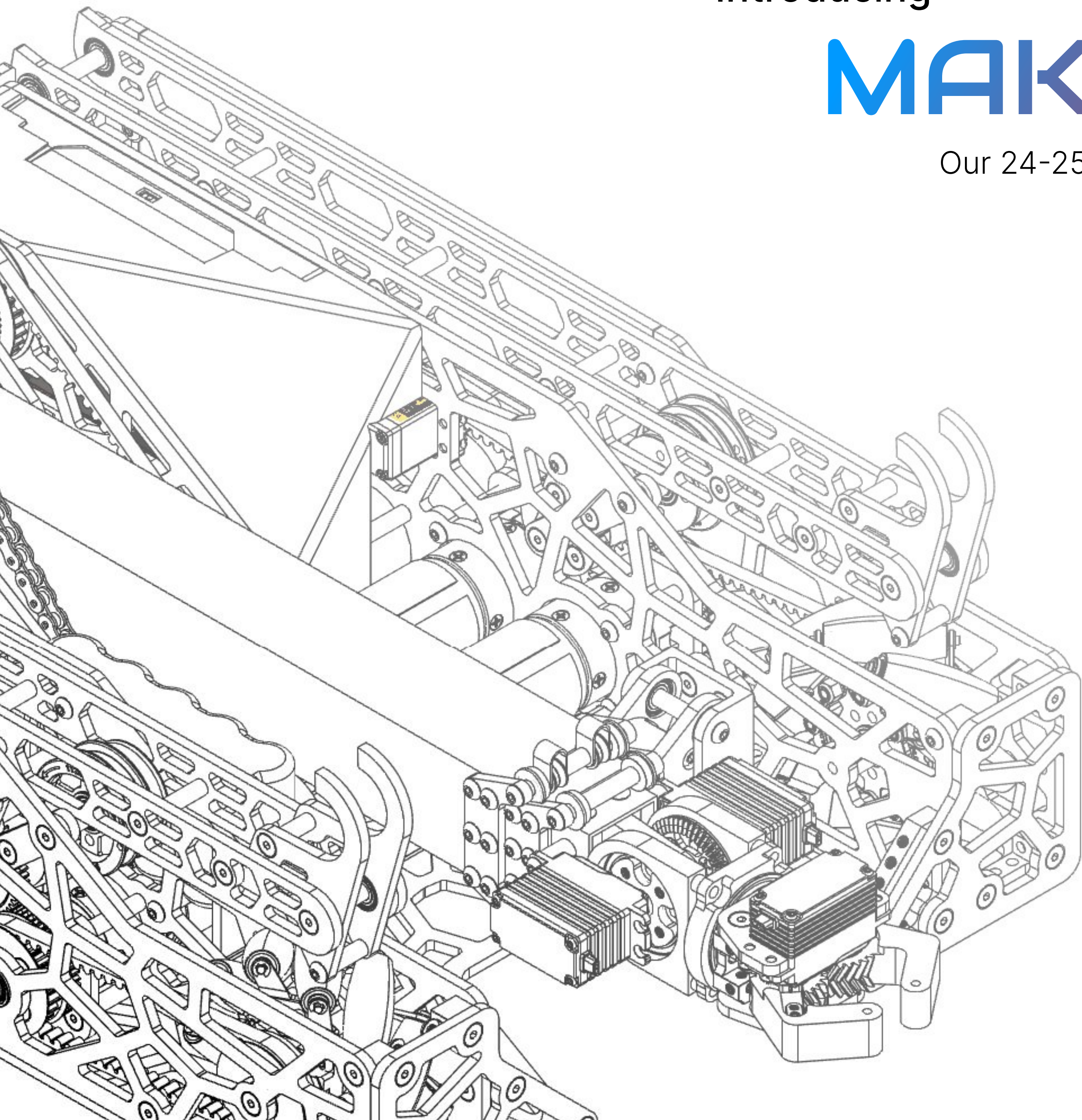
FTC #21579

# TESTING IS OPTIONAL

Introducing

MAKO

Our 24-25 Season Robot



# Introduction

## About the Team

We are Testing is Optional, team 21579, community-based out of Tucson, Arizona. This season we have 3 adult mentors and 11 students, many are returning.

Our primary goals are to innovate and educate. We aim to innovate in hardware and software by using cutting-edge concepts and attempt to develop these concepts further. We strive to educate the students on our team and those in our community.

## Team Management

Our team is broken into three subteams:
Mechanical/Hardware
Software/Programming
Outreach/Business

Each member is able to be on multiple subteams to best suit their interests and skills. To stay organized, each subteam has a team lead that acts as a project manager. To help the team communicate we utilize a private Discord server for 24/7 communication!

## Season Goals

At the start of this season, we had each team member set a goal for themselves, and then the whole team decided on a few goals. Here are some notable ones:

**Team Goals:**

- Use subtractive machining (CNC Milling/Routing)
- Have every single team member learn something new
- Build a visually appealing robot
- Increase our technical outreach efforts

**Notable Personal Goals:**

- Create and utilize a custom Path Follower
- Learn about leadership

## Portfolio Contents

Stating with outreach and the team, then moving to the robot and technical content.

# Sustainability

## Our Sustainability

We define sustainability as the things we do to have a team from season to season. This season that was a focus on Learning, Mentorship, Funding, and Recruitment. During the offseason we had multiple meetings with focuses on programming, CAD, 3D printing, and more. The previous season's team leads lead the sessions with help from our mentors to help boost the leadership skills of those students and with the end goal of skill transfer between students and mentors. Our recruitment this season has gone well and we were able to **recruit 6 new students** to join the team while retaining 5 students from the previous season, with 3 of those students being from our first season.

## Funding

Our team is funded through gracious donations by sponsors and by seeking grants. We greatly appreciate our sponsors for their support, as we wouldn't be able to compete or perform any of our outreach without them.

This season we are grateful to have received funding from:
NASA
RTX
ASW Engineering

## Our Mentors

**Leigh Elkins**
Business, Outreach

**Marcus Kauffman**
Software, Control Theory
*Student Mentor

**John Kelly - NASA**
Hardware, Software

**Kurt Elkins - RTX**
Hardware

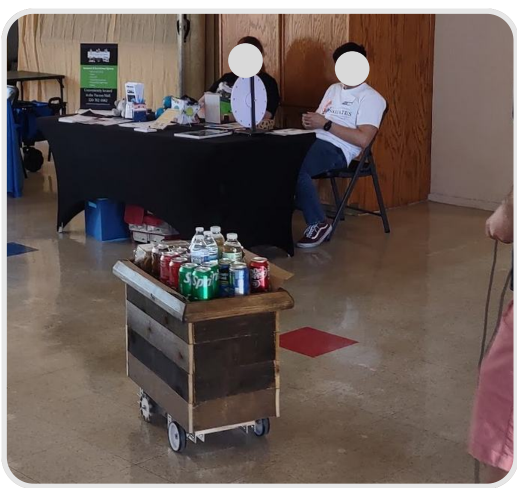
# Community Outreach

## AZ School for the Deaf and Blind

After the conclusion of last season we reached out to the Arizona School for the Deaf and Blind (ASDB) and organized a time to meet and demonstrate our robot to an engineering class. During this time we found out that they planned on starting their own team, and our demonstration **helped inspire the students to want to engage in robotics** more! We have plans to help assist and mentor their team in the future.

## Fall Festival

This year we participated in our parent organization's Fall Festival. We helped to run the arts and crafts tables. The team enjoyed having the time to inspire creativity in kids and we also had time to play some games with other students!



## ESA Vendor Fair

Our parent organization was selected to host a vendor fair for vendors of the Arizona Empowerment Scholarship Account (ESA) where anyone could come to meet and get information from the vendors present to help strengthen their child's education. During the event we had robot demonstrations and sold food/ drinks to **help fundraise for the team while showing off robotics and how awesome STEM is**. After this event we even got featured on the ESA Instagram!

## Social Media

This season we set out to vastly increase our social media reach due to the ease of access and wide reach that we can get through it. Part of our mission is to inspire youth to get into STEM fields and learn about the magic of engineering!

# Technical Outreach

## Microchip MASTERs

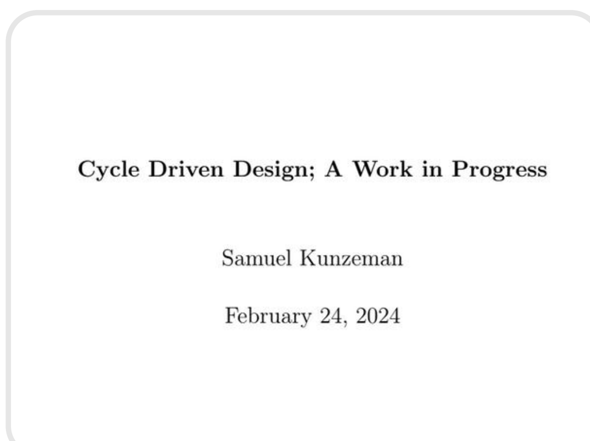
Over the summer we joined a bunch FIRST teams at the Microchip MASTERs conference. The ballroom was open for attendees to come see FTC, FRC, and FLL teams with their robots. During the time we had we had the opportunity to talk to engineers of various specialties and from various companies who had lots of interest in robotics and FIRST. Some of the people we met **gave us awesome ideas on how we could solve problems that we had on our robot!**

## R-Team Robotics

After the conclusion of last season we had the opportunity to have a member of the RTX Tucson Robotics Team (R-Team Robotics) visit us and show some of the amazing robots the team has built. Through his showing of sumo bots, mech warfare bots, and combat robots we **learned** a lot **about the engineering design process** and how you can **make robots from almost anything** to fit restraints!

## Samuel Kunzeman

During the offseason we had the pleasure of having Samuel Kunzeman, an engineer at Caterpillar and FIRST Mentor/Volunteer speak to us about strong design principles. During this time he **introduced us to Cycle Driven Design, which is the basis of our current design process** now! The team learned a lot about design processes and about what Caterpillar does and how massive their machines truly are!



Cycle Driven Design; A Work in Progress

Samuel Kunzeman

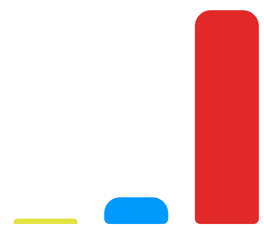
February 24, 2024

# FIRST Outreach

## Impact By the Numbers

### Social Media

**≈710% increase in reach** compared to last season



Views Per Season
- 22-23: ≈50
- 23-24: ≈1050
- 24-25: ≈8500

### FIRST

**50+ teams directly communicated with**

**International Teams**

19043 - CyLiis (RO)
17962 - Ro2D2 (RO)
12887 - Devolt Phobos (MX)

**Out-of-State Teams**

23396 - Hivemind (TN)
9791 - Divide by Zero (PA)

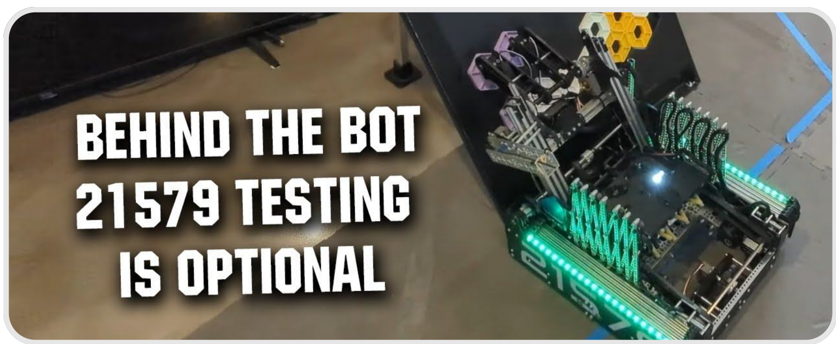
+ Many more AZ, out of state, and international teams met with

### Community

50+ Total hours of outreach

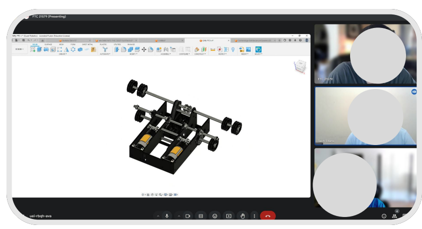
≈10,000 People reached

6 Community Outreach events completed




## FUN Behind the Bot

At the conclusion of last season we had the pleasure of being the **first AZ team to be featured** on FIRST Updates Now's Behind the Bot YouTube series. This opportunity allowed us to **reach a new audience** and take a deep dive on the mechanisms of our robot.

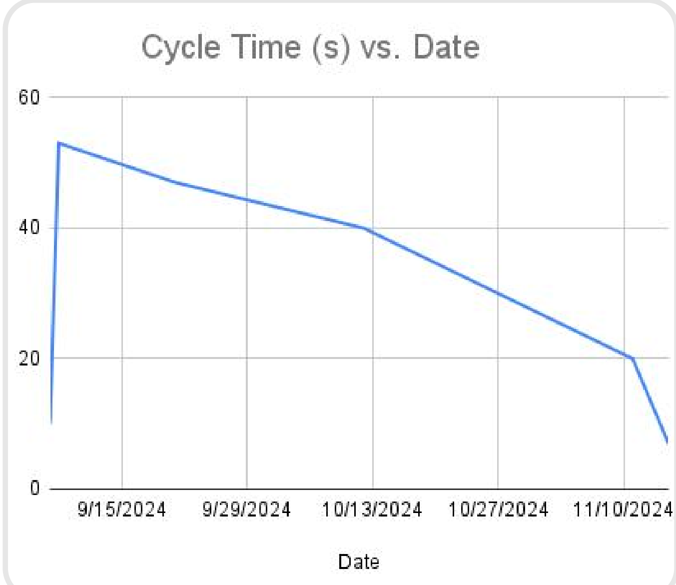


Above you can see pictured us meeting with team 25783 - Tech Titans of Texas. Here is a list of some of the other teams we have met with: 3565, 8617, 21127, 22593, 23222, 6962, 18397, 24395, 14473, 3848, 22105, + more

# Design Process

## Cycle Driven Design

The idea of cycle driven design is to find what systems provide a faster cycle time. To do this we test the bot's cycle times and log them weekly to see if our design changes are making an effect on the cycle time for the bot. We also take into account driver practice improving cycle time and how that could be the reason cycle times improve, not systems. A key value is also reliability, if the system has a fast cycle time but isn't reliable, then the system doesn't meet the requirements.




### CAD

Imagine the system and draw it in complete detail using Autodesk Fusion

### Prototype

3D Print parts and do a test assembly to se if the idea works and is possible to build

### Revise

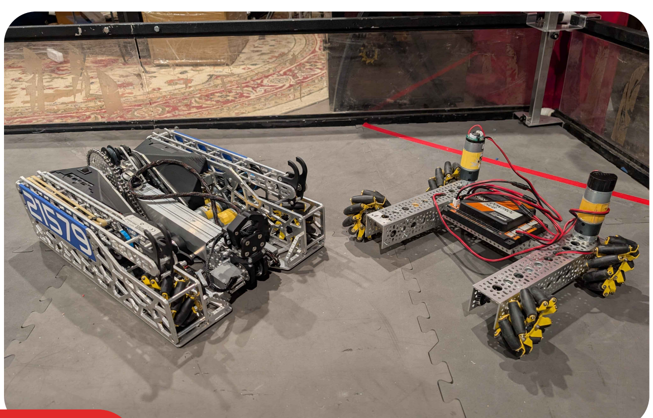
Evaluate the prototype for failure points/ weaknesses/ improvements

### Implement

Add the component to the non-active bot to integrate it with other systems

### Swap

Swap out the bots and add the feature to the now non-active bot to implement more features



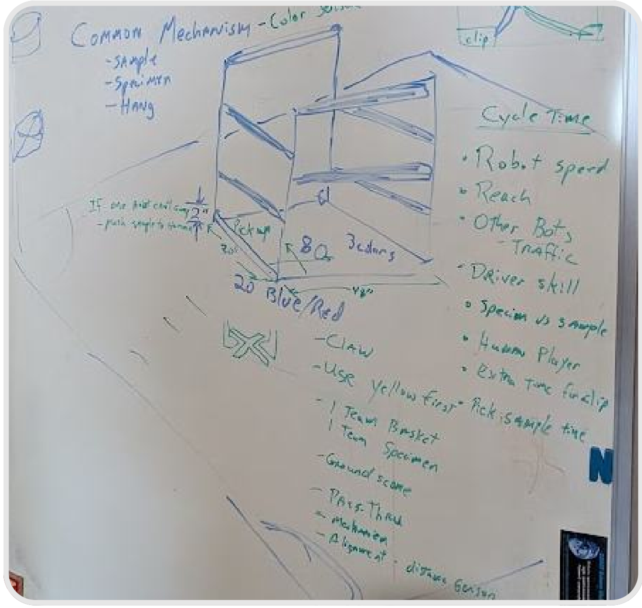
## Dual Bot System

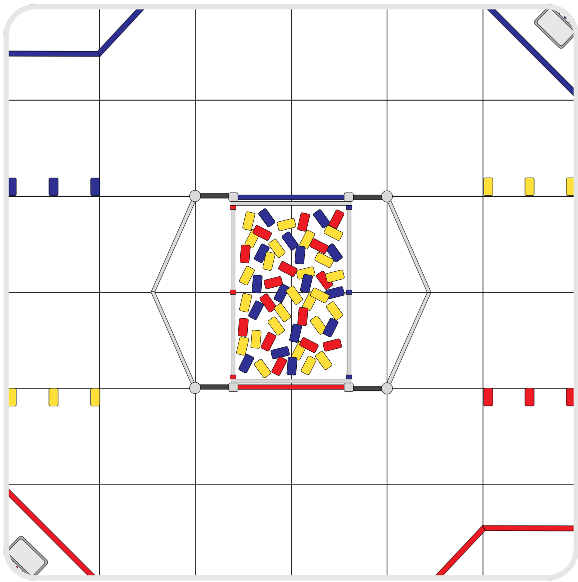
This season we decided to run two bots in parallel. One bot is considered the "active" bot and is the bot our drivers are practicing on and the software team is working on for autonomous and driver enhancements. The other bot is considered "inactive" and is used to test new system by the build team.

# Game Strategy

## Kickoff Strategy

Immediately after the game was announced we began to develop our strategy this season and noticed the high weighting on Samples, so we **started to aim for a sample-focused robot**. A lot of our brainstorming and strategy for both gameplay and robot design have been centered around optimizing our cycle times to the best of our ability. During our strategy discussions we came to the decision that **we liked the idea of a pass-through robot**, meaning the robot will not need to turn around in order to score. The idea of a pass-through has been the guiding principle in the overall design process for the team.



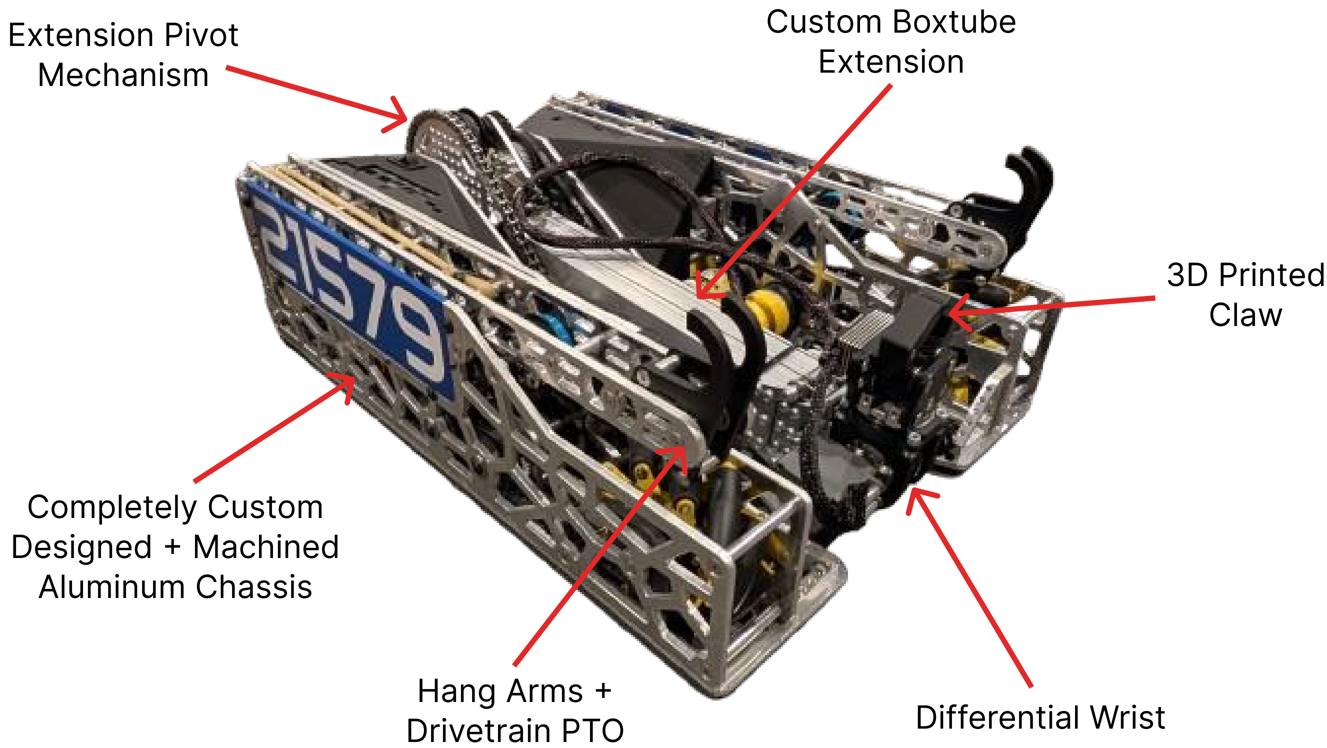



## Interoperability

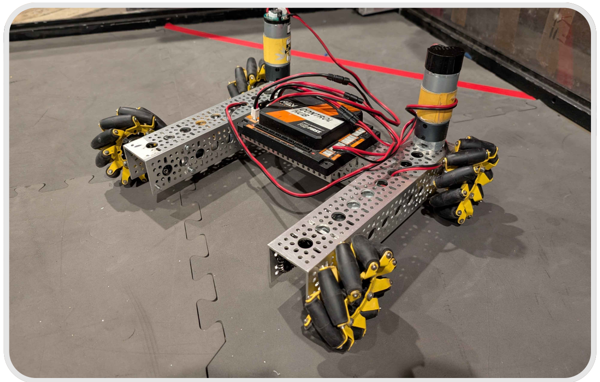
As we moved through the season we decided that **being able to efficiently cycle Samples and Specimen would be highly beneficial**, especially with the new playoff structure. So taking this into account, we have made modifications to our intake and our gamepad control scheme for our drives to be able to have the ability to score both game elements effectively and efficiently. This **updated strategy should help us to work better with our alliance partners** and make alliance selections easier for us, as well as becoming a more appealing alliance partner should we not be a captain.

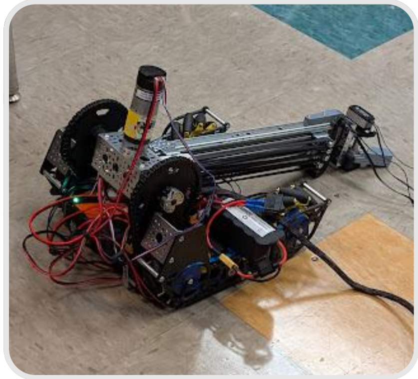
## Key Design Choices

At the beginning of this season, we decided to keep the overall **design of the robot as simple as possible**. This led us to come up with the concept of pitching extension. Instead of needing two separate systems for horizontal and vertical extension, it can be simplified down to a single extension system on a pivot. For our robot built immediately after kickoff to test design prototypes, we used a 4 stage viper slide extension powered by two motors to pivot it. It was a great proof of concept, but we disliked how heavy the viper slides were. This led us to design our current system, a custom telescoping box tube. This style of extension is popular in FRC and uses decreasing sizes of aluminum box section sliding inside each other to achieve smooth and fast linear movement.

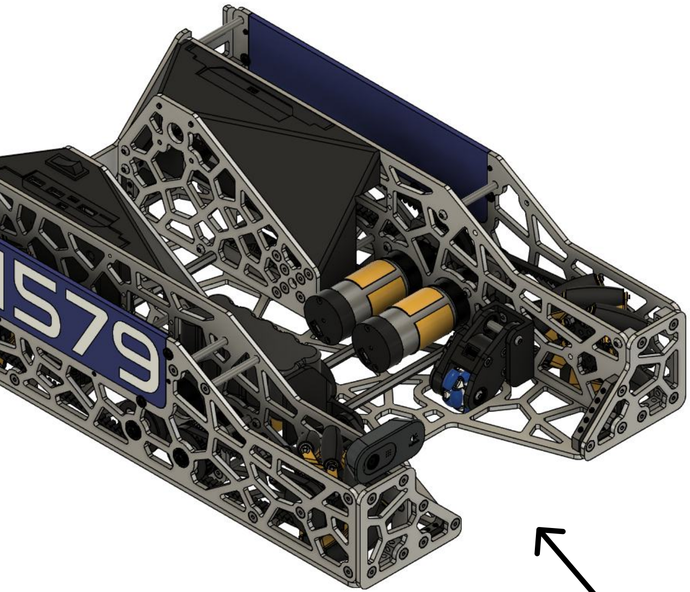



## Past Robot Iterations



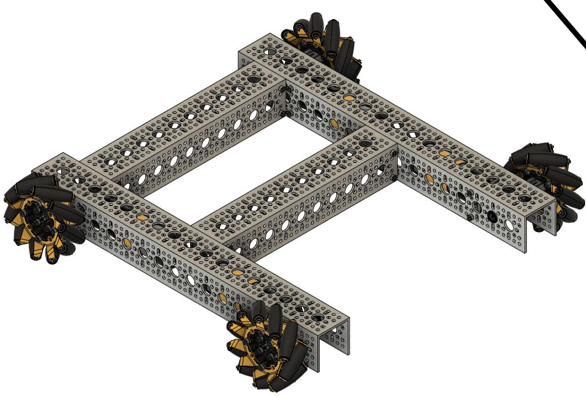


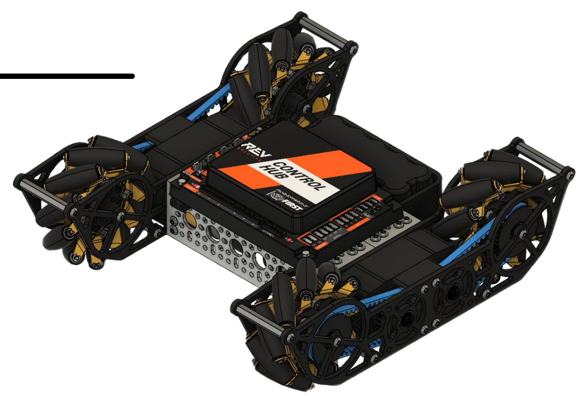
# Drivetrain



## Overview

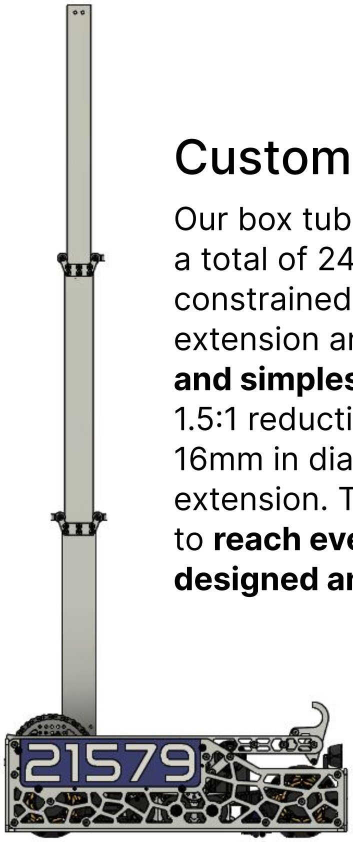
This season we opted to use a **custom parallel plate mecanum drive** in order to achieve simple, yet quick holonomic motion. Each of the 8 plates that make up the frame of the drivetrain are **custom machined in house by our team**. The plates are cut from 4mm 7075 aluminum sheet for maximum strength. This season, we have chosen to pocket each plate, removing unnecessary material and decreasing the overall weight of the robot significantly. We are using 96mm goBILDA mecanum wheels belt driven on a 1:1 ratio by 312rpm motors for a theoretical top speed of ~5 ft/s.





## Custom Odometry

To localize the drivetrain on the field during autonomous and figure out where the robot is, we use a combination of custom dead wheel odometry pods and a goBILDA Pinpoint odometry computer to achieve quick and accurate localization. The odometry pods use REV Through Bore Encoders and 35mm omni wheels held together by a custom designed and 3D printed frame. The Pinpoint allows us to **read the encoders and the internal IMU up to 1500hz**, much **faster than possible on the REV hubs**, which would read **between 30 and 90hz**.




## Custom Boxtube Extension

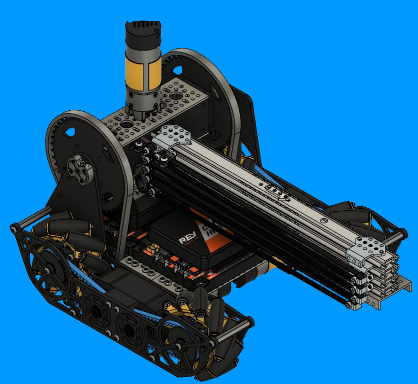
Our box tube extension system uses 1.75”, 1.5”, and 1.25” box tube sections and a total of 24 internal and external bearings to keep each section properly constrained and running smoothly. The system works by utilizing cascading extension and continuous retraction to **allow for the fastest extension time and simplest stringing**. The extension is run on a single 1150rpm motor on an 1.5:1 reduction and an effective 32mm spool. In reality the extension spools are 16mm in diameter but the cascading effect doubles the speed of the extension. The maximum extension of the box tube is around 45”, allowing us to **reach every scoring height required**. The entirety of the **mechanism was designed and in-house machined by our team**.

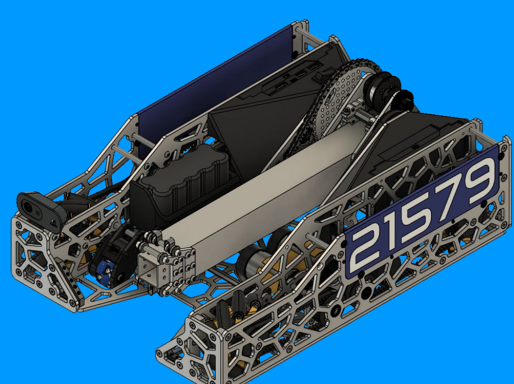
## Pivot Mechanism

The entire box tube extension is mounted to the robot on a robust pivoting mechanism. The pivot is actuated by a 312rpm motor on a 4.2:1 chain reduction for an effective rotation speed of ~75rpm. To track the rotation of the pivot, we are using an absolute analog encoder. The analog output never resets, so the position is known at all times.

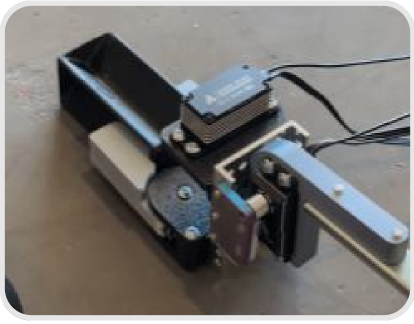
## Early Iteration

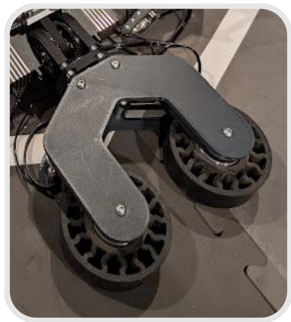
At the beginning of the season, we explored the possibility of using goBILDA Viper Slides to extend our robot's reach. However, after considering their significant weight and the amount of friction they had in the linear motion, we decided to opt for the custom boxtube design instead.

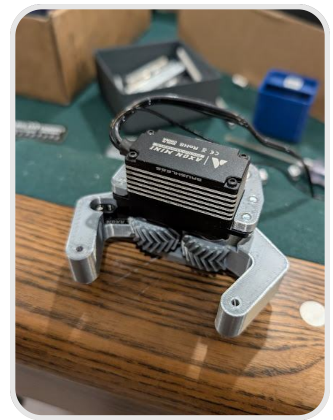




# Manipulator

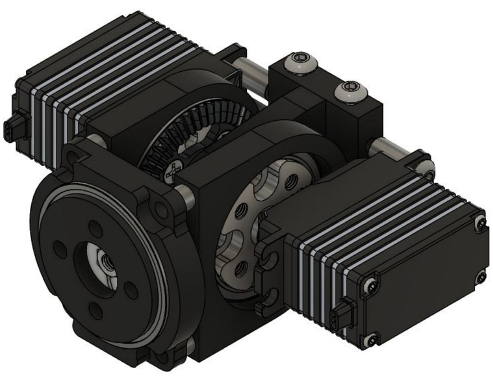






## Claw

**Version 1** - A modified version of a previous season's claw. We found that the accuracy needed to grab game elements too great.
**Version 2** - An active roller intake, where the wheels spun the game elements into its grip. Overall, the design was too heavy and bulky.
**Version 3 (Current)** - A complete redesign of the first version designed to require less precision and to be more compact.



## Differential Wrist

To get maximum mobility and freedom when intaking and scoring game elements, we decided to implement a **2 degree of freedom differential wrist**. It works by using two servos driving the side gears of a differential. When the servos turn in the same direction, it causes the pinion gear to lock up, moving the wrist up and down. When the servos turn in opposite directions, it causes the pinion gear to rotate, twisting the wrist left and right. **Having two degrees of freedom at the end of the extension allows us to intake game elements at any angle**.

## Kinematics

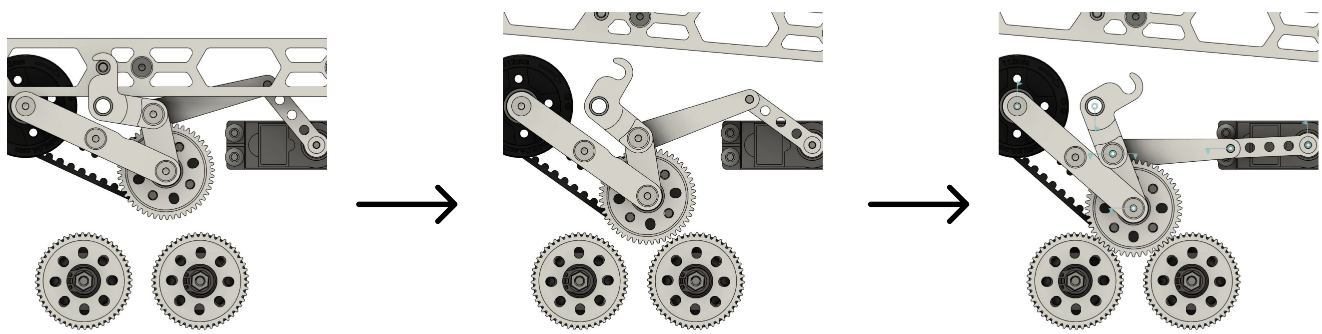
**To help us calculate and derive the positioning of the wrist, we utilize kinematics**. We use the equations to the right, where θa is the angle/pitch of the wrist, θt is the twist of the wrist, and m1/m2 represent the positions of the servos. You might notice that these equations only calculate the current position, so we can use algebra to rearrange the equation in code to figure out the necessary servo positions for the desired output.

$$\theta_t = \frac{m_1 + m_2}{2}$$

$$\theta_a = \frac{m_1 - m_2}{2}$$

## Drivetrain Power Take Off

This year we wanted an ascent mechanism that aligned with our goals for the season, those being having a simple, yet elegant robot. We wanted to **avoid adding additional actuators** to our robot, adding more mass and taking up more space. This led us to develop a drivetrain power take off (PTO) system to power our ascent mechanism. The **PTO allows us to transfer the power of all four drive motors to our hang spools**. There are two PTO's on the robot, one for each side, and each one is driven by a goBILDA torque servo. The mechanism utilizes an over-centered 4-bar linkage to lock the pinion gear into place. Two spung loaded hang arms are placed between the drivetrain plates and are released when the PTO engages. Driving the drivetrain motors causes the spools to start winching down on the hang arms, lifting the robot off the field.



The PTO is disengaged. During this state the hang arm is locked in position and the robot will drive as normal without worrying about the hang arms flipping up.

The PTO is half engaged. This step of the process allows the hang arms to use their springing to fling up and into position. Since the gears aren't engaged, driving will continue as normal and the hang arms will not retract.

The PTO is fully engaged and the linkage is over-centered to prevent the PTO from disengaging. The spool for the hang arms is now powered by the drivetrain motors and hanging can commence.

## Controlling the System + Future Plans

This subsystem has a lot of moving parts, so control is essential. To help automate this sequence, we utilize a Command (read more on pg. 13 about commands) that is multi-staged and helps the driver have to use less button presses and less precision. **Utilizing the current draw of the motors**, we are able to **automatically detect when the robot has completed the hang**, as the motors will near their stalling current, telling us to stop spinning them automatically.

You might notice that we only have a level 2 ascent, while testing the system we found that our plan of using the boxtube extension to pull us up to the second stage was not strong enough, the motor does not have enough torque. To rectify this, we plan on utilizing two extension motors or another PTO similar to this one.

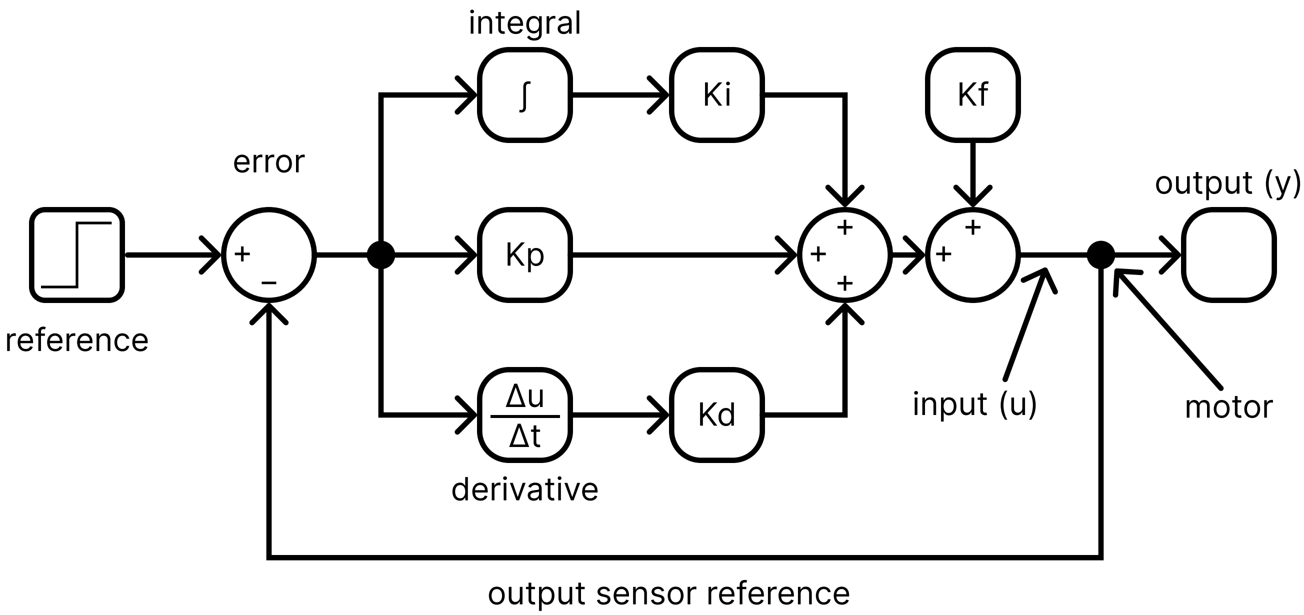
# Commands + State

## FTCLib Commands

To aid in writing effective and easily readable code, we utilize the FTCLib command base paradigm within our code. What this allows us to do is create “commands”, which are similar to a macro you might have on your computer. These commands can be a single event (like a claw opening/closing) or a sequence of events (like an entire autonomous program). Using this paradigm allows us to **create sequences of events** significantly **easier and makes iteration** on autonomous **faster**.

## PIDF Controller

To aid in control of both our pivot and extension subsystems, we utilize a PIDF controller for each. The Proportional Integral Derivative Feedforward controller is a modified version of the standard PID controller that introduces what is known as a feedforward. PID works to “close” a software loop, working solely with the information provided by sensors. The F term (feedforward) “re-opens” the loop by predicting the mapping between planned inputs and outputs. We utilize this term to work against gravity, since gravity is a constant. When combined with the rest of the PID controller, we essentially have a closed loop system while having compensation for gravity.



# Autonomous

## Our Goals

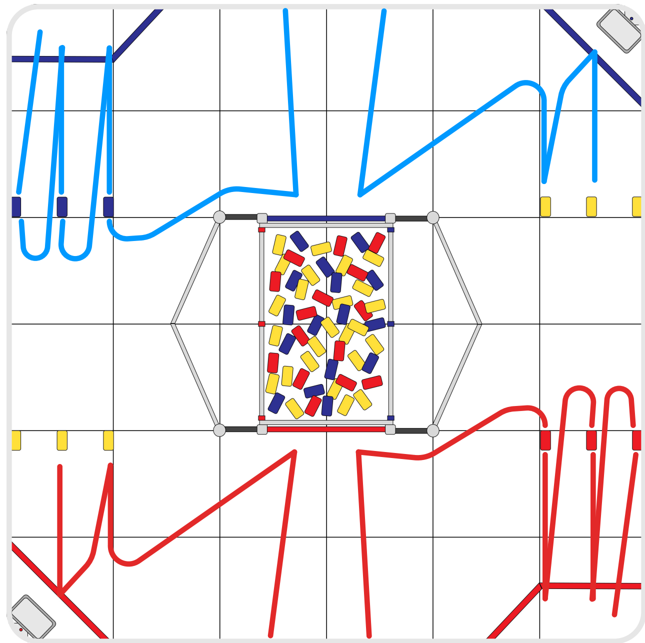
**Sample Auto (37 pts):**
1. Score preloaded specimen on the High Chamber
2. Intake + Score the Placed Neutrals in the High Basket
3. Park in the Observation Zone

**Specimen Auto (40+ pts):**
1. Score preloaded specimen on the High Chamber
2. Push Placed Alliance-Specific Sample to Observation Zone
3. Intake Specimen from Human Player
4. Score Specimen on High Chamber
5. Repeat 2-4 as many times as possible
6. Park in Observation Zone

## What we have

**Sample Auto (29 pts):**
1. Score preloaded specimen on the High Chamber
2. Intake + Score the Placed Neutrals in the High Basket (x2)
3. Park in the Observation Zone

**Specimen Auto (13 pts):**
1. Score preloaded specimen on the High Chamber
2. Push all 3 alliance specific samples into the Observation Zone



## Custom Path Following

Over the last year and a half we have been working with FRC team 2141 to **develop and use a custom path follower** as a part of our swerve drive software library. This path follower uses a **mix of vector fields and look-ahead methods** that we have found to work well. This project is still a work in-progress that we hope to implement in our code by 2025.

quail

## Our Plan of Action

We have quite ambitious goals for autonomous this season, so to help us achieve these goals we have created a timeline for what our autonomous should look like at various points of the season. As of now, we are on pace and have overcome hiccups along the road to a strong autonomous.

# Driver Control

## Feedback and Automation

A significant amount of this season's game revolves around repetitive actions, so we decided to try and automate as many of these actions as we can. Utilizing FTCLib made this significantly easier, as we were able to string together sequences commands to create new commands for automation. **We are able to score both Samples and Specimen with a single button press from the driver**. Having these automations allows us to condense our control scheme to utilize a single gamepad, meaning a single driver. Through past experience, we believe that having a single driver decreases the likelihood of miscommunication causing a mistake in driving and strategy.

## Lots of Safeties

To help our drivers not violate extension limits and keep the robot from breaking itself, we have multiple driver safeties implemented. The most important for this season is limiting the extension distance and pivot angle based on the other to stay within the  20in x 42in extension limit. The robot will also prevent the wrist from moving places that could damage wiring, and the same with the claw to prevent burning out a servo.