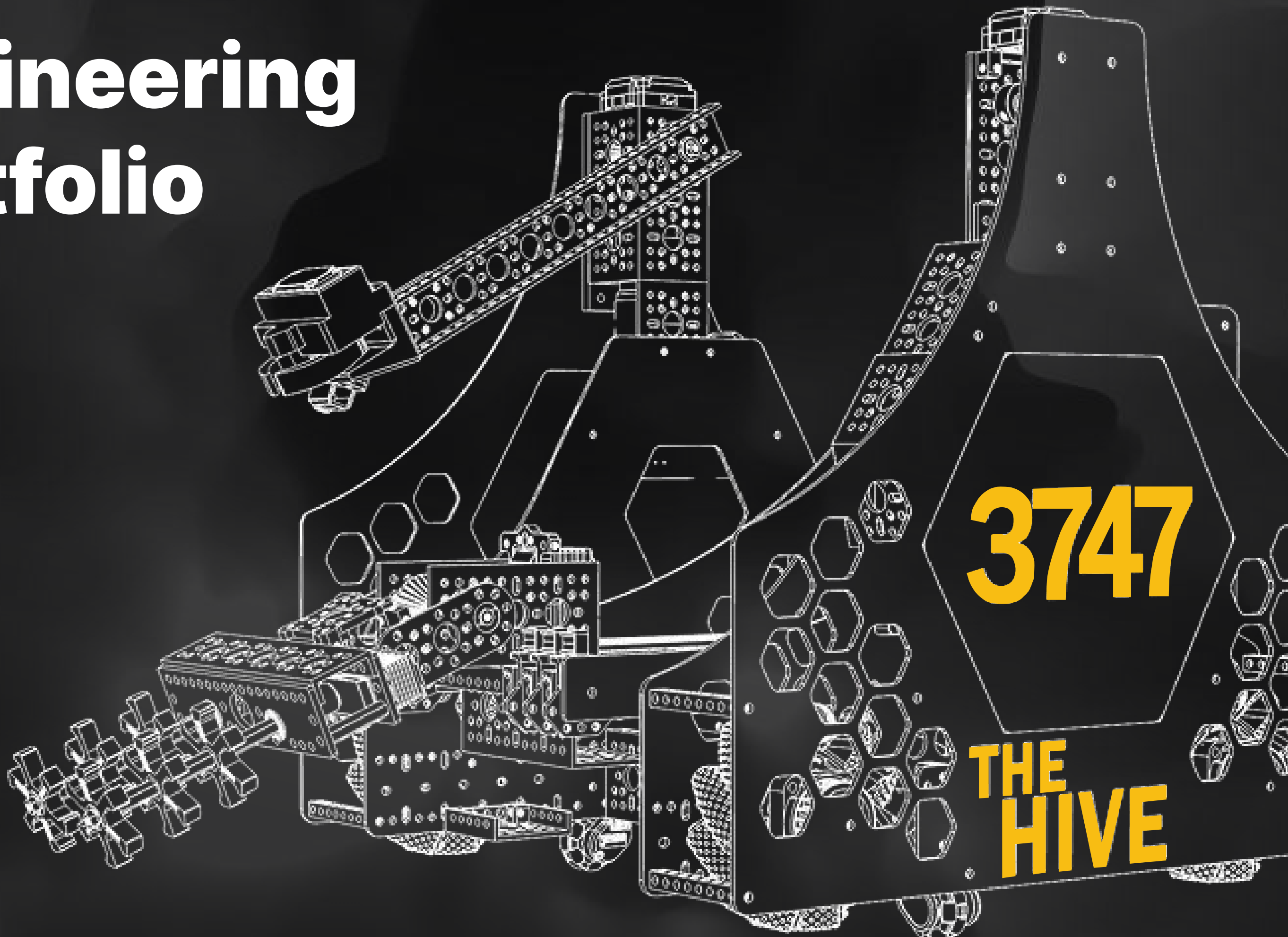
The Hive 3747

Engineering Portfolio



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Team Goal:

Our team goal is to be a **high-performing** team. What that means to *us* is using **our knowledge** to **pollinate the FIRST community** and **build an incredible robot game.**

Pollinating the FIRST Community

Our overall goal of **pollinating** is split into **four** sub-goals:

1. **Attract**, **engage**, and **support** people **into FIRST.**

2. **Acquire mentors** by recognizing a need and reaching out to our current network and finding people that provide real support **to engage with us and other teams**.

3. Share our **knowledge and time** to **build our competition.**

4. **Bring value** to our community.

Our Story:

The Hive is a **16-year-old** team from Sandy, **Utah**, USA. We're a **school-based** team at Beehive Science & Technology Academy.

Last year, we went to **Worlds** for the **first time ever**. Using our experiences from last year, we wanted to know how to **improve ourselves further.**

We realized that just as our **mentors gave us their knowledge**, we needed to **pollinate the FIRST community** with our knowledge.

FIRST is more than just robots— it's a community.

Season Plans - 11 months ago, we wrote down 67 plans for this season. Throughout this year, we've achieved over 84% of these plans, and exceeded our expectations for quite a few. Below are those we've achieved:

Mechanical Plans:

- ✓ **CAD Learning:** Hosted classes over the summer, 5 team members proficient in CAD
- ✓ **Parallel Plate Drivetrain (PPDT):** Designed a custom PPDT in CAD and built it using Aluminum Plates.
- ✓ **Misumi Slides / Extendo**
- ✓ **Sensors:** Touch sensor, color sensor, and odometry.
- ✓ **Wiring & soldering:** Multiple members learned soldering and designed custom wiring holder for Hubs.
- ✓ **Surgical Tubing:** Attempted, but we found a better way to intake.
- ✓ **Print TPU:** Recruited 3D Printing mentors and learned how to print TPU and other materials.
- ✓ **Organize Room**
- ✓ **Modularity:** Subsystem parts are designed with modularity in mind, our slide mechanism needs only 4 screws to take apart!
- ✓ **Look at High-Performing Teams:** Learned from teams like 5026 Tesla Coils and 11212 The Clueless for linear slides.
- ✓ **Custom Metal Plates:** Recruited 2 mentors, robot has Aluminum plates which we cut & powdercoated ourselves.
- ✓ **Smaller Robot:** Our robot is 17" in all directions.

Programming Plans:

- ✓ **Programmer on Drive Team**
- ✓ **Update RR 1.0**
- ✓ **Other Path Following:** Currently using PedroPathing.
- ✓ **Refactor TeleOp:** Much smarter, with a config mode, faster loop times, and auto. actions.
- ✓ **Create Programming Standards**
- ✓ **FTC Lib Commands:** Currently using FTC Lib commands as well as Switch Cases for automation.
- ✓ **Apriltag Relocalization**
- ✓ **Adaptable Autonomous:** Auton is smart and has failsafes, using sensors and timeouts.
- ✓ **Look at High-Performing Teams:** Learned from teams like 12791 Iterative Intentions for PedroPathing.

Business Plans:

- ✓ **CAD Computer**
- ✓ **Gene-Haas Grant**
- ✓ **Reach Out to Companies:** Over $60k acquired this year!
- ✓ **Robotics Camp:** Raised over $9,750!
- ✓ **Website**
- ✓ **Rookie Course**
- ✓ **Mentor UK Team**
- ✓ **Attend Wasatch Mountain Invitational**
- ✓ **Host Beehive Qualifier**
- ✓ **Visit the Boxworks Warehouse**
- ✓ **Start FTC Team:** Started & mentored 25817 Cyberviking 1!
- ✓ **Attendance Policy**
- ✓ **Big Calendar in Room & Google Calendar**
- ✓ **Use Slack:** Switched to Slack and made a Slack bot for automated E.N. Entries and Scouting!
- ✓ **Clean UP!**
- ✓ **New Member ~1:1 Ratio**

Building the Community of *FIRST* -

FIRST is built by teams, volunteers (you!), and mentors, and our main goal this year was this: **Have a meaningful impact on others in the *FIRST* Community.** Our impact this year was immense, as we introduced thousands to *FIRST* and made real connections with mentors, parents, students, and others.

Recruiting - Sustainability is hard,

but we've **built a robotics culture at our school.** With **less than 400** students in HS, we've received **over 60 applications** to join our team!

Recruiting Process:

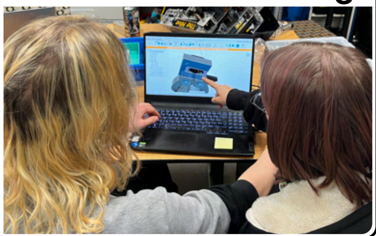
Advertise (MAY-JUN) → Sent emails to both current and prospective students to spread the word that we're recruiting. Hosted information meetings for those interested to learn more.

Train All Interested (JUN-JUL) → After a short interview, we bring those interested to outreach events and start training them with experienced members and with mentors.

Decide Final Team (AUG) → Considering needs of the team for specific teams, the passion of the members, and how well they work with our team, we decide on the final team members!

Training - Rookie members aren't

treated like outcasts— we immediately start working **alongside them**, rather than above them. We believe in **learning by doing**, and both us and our mentors follow that strategy to teach others.



Captain
Bus. Lead

Team Management
Planned Team-Building activities, corroborated w/ members abt. plans.

Prog. Lead

Java Logic Flow
Took prog. courses in order to improve FTC prog. and logic understanding.

Mech. Lead

CAD & Leadership
Learned higher level CAD techniques as well as leadership skills.

Business

Task Organization
Organized tasks, ensured they were being updated, facilitated team comms.

Scheduling & Planning
Kept both online and physical calendar constantly updated.

KEY: Member | Skill Plan

6 Team Members are new to FIRST, 8 to FTC

Programming

AI Computer Vision
Researching, setting up, and tuning autonomous sample detection with CV.

Autonomous Pathing
Learned RR and later PedroPathing & FTC Lib Commands for Auton.

Adv. Sensor Tuning
After trying diff. color profiles, tuned REV Color Sensor for auto-intake.

Mechanical

Rapid CAD Iteration
Using a variety of testing, rapidly iterating parts in CAD before manufacturing.

Complex Wiring
Organized wiring on robot and learned basic soldering for robot and for other materials.

Efficiency in Parts
Learned how to properly design, manufacture, and put together subsystems.

Design Process
Learned the design process, incl. proper brainstorm & prototyping & it's importance.

Basic CAD
Using courses, mentors, and exp. members, learned basic CAD in Fusion 360.

Team Org Plans: Increase Productivity Efficiency

Slack
Over the summer, we switched our **communication** to Slack. On Slack, we're able to utilize **Slack Lists**, which is a **Scrum-based** platform where we **organize our tasks.**

/en

We also developed a **custom Slack bot** which allows us to make **engineering notebook entries** with a simple command.

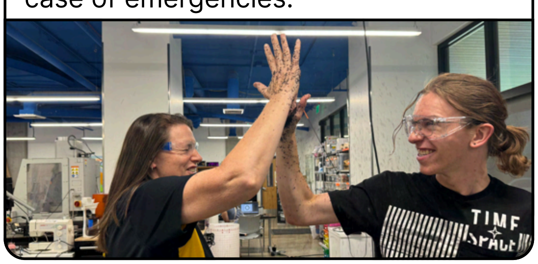
Calendar
We have an **online and in-person calendar**, which are both constantly **updated** by our **business team**.

Meeting Schedule
Our meetings are **based by subgroup** to maximize productivity.

Traffic Lights
In our room, we have timed regulation **traffic lights keeping us on task.**

- Look at our tasks and decide what to work on
- Make an Eng. Notebook entry and clean up
- Leave

Subteam Process
Our subteams are based on **individual preference**. Although that subteam is our **main focus**, **everyone knows what everyone else is doing**, and can sub in case of emergencies.



Team-Building
During our **whole-team meetings**, we run **team-building activities**, like learning about different personality types.

Everyone Participates
Mentoring is a **huge priority**, and everyone on our team is **committed to mentoring other teams weekly**. Whether in-person or virtual, we all prioritize our mentorships.

Teams We've Mentored This Season

UT / USA FTC
24703 | Celestial Robotics

General mentoring, mainly in build and programming.
Hosted them at our school.

UT / USA FTC
19389 | Angry Aliens

Programming mentoring, specifically with drivetrains.

WV / USA FTC
25817 | Cyberviking 1

Started and **weekly mentored** this **one-man team.**
Flew him to Utah so he could compete with us!

"None of this year, not any of it, would have been possible without [The Hive]."

UK INT FTC
21221 | Gear Sub Zero

Team management and Engineering Portfolio mentoring.

Japan INT FTC
23232 | SAKURA Tempesta

Team management mentoring, **one of the first teams in Japan.**

UT / USA FLL
3553 | BeeSTAR
23621 | BeePositive
54318 | B⁴
28325 | BeeBotics
28326 | DodecaBeedron

Our Sister FLL Teams.
We mentor these teams weekly, and started them last year.
BeeSTAR won the Champions Award and is here at Worlds with us!

AZ / USA FTC
26037 | Cyber Tigers

Portfolio mentoring, met online.
Won Design & Think at multiple qualifiers.

"I don't think we would've won Think or Design if it weren't for the advice you've given"

GA / USA FTC
22581 | Red Ring Of Death

Portfolio mentoring, met online.
Won **Inspire 3rd** at League Tournament.

PA / USA FTC
9791 | Divide By Zero

Mentored in fundraising,
Won **Inspire 1st** and **Winning Alliance 1st Pick** at Qualifier, and the **Connect Award** at PA States.

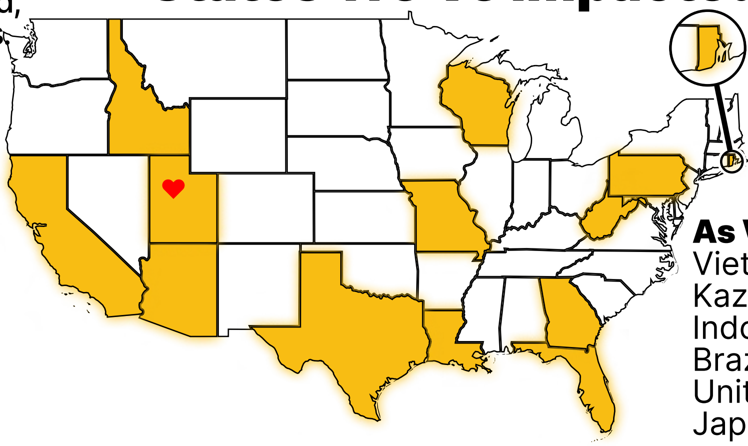
Mentoring: **504 Hours**
Mentored **13 Teams**
From **4 states** & **3 countries**

We've **assisted 27 teams** from **19 regions** across the globe!

Teams Assisted - We assist teams through online messaging like Instagram, Discord, or E-mails, or through online/in-person meetings

RI, USA	636	Occam's Razor Clams
TX, USA	26300	Anomaly
GA, USA	14943	Weber RamBots
Vietnam		FGC Team Vietnam
Kazakhstan	25547	SPIRIT
MO, USA	23534	Wombots
CA, USA	10092	Green.Griffins;
Indonesia	27685	DAYS
FL, USA	3830	Violet Fusion
TX, USA	25679	The Cosmobots
LA, USA	19824	Pride Robotics
Brazil	23501	Nexus
WI, USA	13201	Team Hazmat
CA, USA	14259	TURBΩ V8
TX, USA	25783	Tech Titans
TX, USA	6272	Iron Eagles Prime
NJ, USA	13302	MKA Robotics
TX, USA	23361	Cosmobotics
CA, USA	5773	Ink and Metal
FL, USA	8617	Techno Tigers
UT, USA	26630	Chaos²
UT, USA	19922	Iron Lions
UT, USA	20515	Cubed ETs
UT, USA	8641	The Masters
UT, USA	21676	T.C.P.G.
UT, USA	16028	Mecha Knights
ID, USA	5026	Tesla Coils

States We've Impacted



As Well As:
Vietnam
Kazakhstan
Indonesia
Brazil
United Kingdom
Japan

Growing a Worldwide Community of *FIRST* - The community we support has grown immensely each year. Last year, we assisted/mentored teams from just **2 regions**, meaning **our impact has grown to 10x the regions.** Last year we mentored 7 teams and assisted 7 teams. The **amount of teams** we mentored & assisted has grown by **2x!** Our goal has a team has been to find opportunities to help others and bring people into *FIRST*– a goal that we think we have not only met, but exceeded!

This Year, we connected 12,278 people with *FIRST*.

2,239 Team Outreach Hours

504 Team Mentoring Hours

51 Outreach Events

Summer Camp

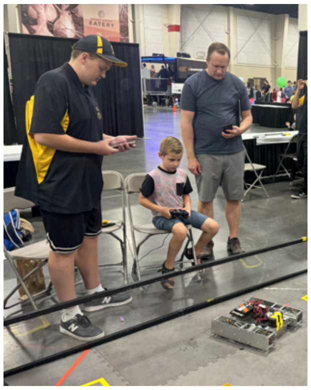
Summer Camp - We **organized**, **hosted**, and **ran** a **2-week summer camp** for **K-7th graders**. Using **FLL Mission Models** from previous years, the kids split off into **teams** and **designed** and **programmed** a robot to complete their missions. At the **end of the week**, they "competed", and **each kid received an individualized award**.

We raised $9,750 and had over 120 kids participate!


Other FLL Events:

- FLL Explore Tryout
- Building Battle Bots for Weber State Uni.
- FLL State Champs.
- FLL Explore Juding
- FLL Hillcrest Qual
- FLL Tryouts
- Donate Robot Table

Lessons Learned from Outreach



At the beginning of the year, we did **interactive Robot Demos** using our Parallel Plate Drivetrain. Although this was fun, it **didn't have the most retention**.
At our **Fall Festival**, we came up with the idea to use our **Centerstage robot** as an **interactive Claw Machine** to **win candy**, and it was a success! ↓

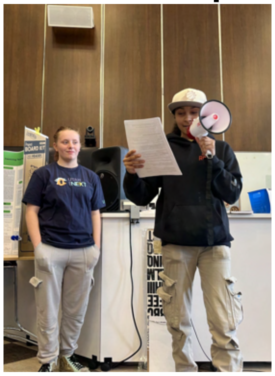
CyberViking 1

CyberViking 1 - Over the summer, we met CJ, a **deaf robotics kid** from West Virginia (Chesapeake). We **started** his team and **mentored** him **weekly**, but unfortunately he **wasn't able to compete** due to Qualifier Registration issues. We **paid for him to fly to Utah** and **compete** at a **qualifier** with us, and **broke 2 State Records** and were **Winning Alliance** with him!

Come to our pit to learn more!


Society of Women Engineers (SWE)

Society of Women Engineers (SWE) - We were **invited** to join other teams at a SWE event, where we used last year's robot as an **interactive demo**, **set up our Worlds pit**, *and* a few of **our members spoke at the event**.




Other Demo Events:

- Robot Room Tours
- STEM Day on The Hill
- Fox 13 News
- Fundraiser Dinner
- Math Matters
- Fall Festival
- STEM Fest
- STEM Expo
- FanX
- Leonardo Outreach

Beehive Qualifier, Scrimmage, Build Day

We **organized**, **hosted**, and **ran** the **first ever FTC Qualifier at our school**! We **hosted** the **scrimmage** before the qualifier to learn how to properly **host** a smooth **event**. Our **qualifier** was **amazing**, ended early, and our **PDP** said it was one of the **best qualifiers** she's ever seen!

Other FTC Events:

- Drive Practice Hosting
- CAD Classes
- WMI
- Season Kickoff
- Ri1W
- Rowland Hall Scrim
- Idaho Scrimmage
- Sister Soiree
- FTC PC Qual
- YouTube Interview

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Acquiring Sponsors - Using our **connections** with **mentors**, applying to **grants**, and **spreading the story** of our team to the **industry**, we're able to **acquire long-term sponsors**. These sponsors aren't just a source of money—they're **people that believe in us** and want to **invest in our teams**. We use their funding for **real, meaningful impact**, impact that can be shown in **numbers and** in **stories**.

Financial Sustainability Plan

Our financial sustainability plan is split into a 3-step process:

1. Apply for grants & fundraise

Over the **offseason**, we **apply to grants**. Working with **industry companies** allows us to make **meaningful long-lasting connections** and acquire mentors. We also **organize fundraisers**, like our **Fundraiser Dinner.**

Example: Organizing our **first-ever Summer Camp** which raised **$9,750** and **spread *FIRST*** to **over 120 kids!**

2. Use our money to succeed

Part of our budget is **spent on robot parts, tools, and mechanisms**. Last season, we **switched our parts system** from Actobotics to GoBilda, and part of our money has been spent on switching this part system and **building an inventory of parts.**

Example: Our budget has allowed us to have **3 active robots** at the same time, **enhancing our Driver Practice!**

3. Use our money to help others

A large portion also goes to **outreach**. We spend our money to **help other people and broaden our impact.**

Example: A **team we started**, Cyberviking 1, **wasn't able to compete** in a competition due to registration issues. We **paid for him to come to Utah** and **compete with us**, and **broke 2 state records** along the way.

Learn more on Page 4!

Where?	How Much?
DoD Grants	+ $4,500.00
STEM Action Center	+ $3,600.00
Motorola Foundation	+ $4,500.00
GoFundMe & Donations	+ $1,945.00
Beehive STA Grants	+ $3,000.00
Friends & Family	+ $16,770.00
Other Donations	+ $3,724.00
Worlds Funding	**$48,539.00**
Worlds Spending	**$48,080.62**
Summer Camp	+ $9,750.00
Fall Festival	+ $1,179.00
$150 Club Fees	+ $2,250.00
Parker Hannifin	+ $2,500.00
Gene Haas Foundation	+ $2,000.00
Clarendon Foundation	+ $2,000.00
Other	+ $7,698.00
Regular Season In	**$27,377.00**
Regular Season Out	**$26,593.40**

Funding for Worlds - The first section in this chart is our Worlds funding and spending, which includes both our team and our FLL team (who is here at worlds with us). For middle schoolers, funding is difficult, and we worked directly alongside them to plan events, grants, and fundraisers which we could attend together, easing the effort they had to put in while increasing the money we raised.

Our Money's Impact:

2,239 Outreach Hours
12,278 People Impacted
13 Teams Mentored
19 Teams Assisted

Mentor Engagement

To Acquire Mentors:

We **recognize a need** and **reach out to our current network** and find people that **provide real support to engage with us and other teams.**

Continuing Mentors


Royd Nelson
Aquaveo
Mech Eng


Annie Drennan
Beehive
Team Org


Ben Holt
Motorola
Java Prog


Daniel Bryant
Beehive
Eng Process


Kirk Drennan
DoD
Material Sci


Sarah Bentley
Beehive
3D Printing


Nicole Brooks
STEM Action Center
CAD Expert

Information Cascade

Information **transferred to us by mentors** is then used by us to **mentor other teams.**

For Example:

Prog. Mentors

Prog. Team

Other Teams

How We Learn From Mentors:

Mentors help us by providing us with their **expertise, knowledge, and experiences**. They ***never*** work on anything directly. **We believe in learning by doing**, and that belief applies to *all* mentors.

7 New Mentors We Acquired

Mentor	Need Fulfilled
 **Wayco Scroggin** ***COO of Jacobsen Innov*** **Machining**	**Machining and preparing aluminum plates on drivetrain.**
 **Peter Hammond** ***UtahRealEstate.com*** **Programming**	**Taught Test Driven Development, Fail Fast Prototyping, and Sensor Prog.**
 **Asim Kablan** ***Engineering Student*** **Drive Strategy**	**Alumni from years before, brought back for expert driving experience.**
 **Parveen Gupta** ***Sphera Solutions*** **Programming**	**Machine Learning and Sample Distribution Recogntion.**
 **Gary** ***Raytheon Company*** **Powder Coating**	**Powder coating aluminum plates on drivetrain & slides.**
 **Brent Drennan** ***Yale Cordage*** **Stringing Slides**	**Custom-producing strings for linear slides and providing recommendations.**
 **James** ***Engineering Student*** **Design Strategy**	**Providing past experiences to shape current decisions.**

Measuring Mentor Success

We **introduce** our mentors to *FIRST* and **ignite their passion** in **robotics**. Not only do they **voluntarily** put **extra hours** in for our team, but they also go on to **mentor other teams** and **volunteer** at *FIRST* events. Compared to **last year**, **our mentors have spent double the hours in robotics**:

Volunteering in *FIRST*: **248** *hours*

Hours Out of Room: **510** *hours*

Hours in Room: **3,708** *hours*

last yr. **1,998** *hours* → this yr. **4,218** *hours*

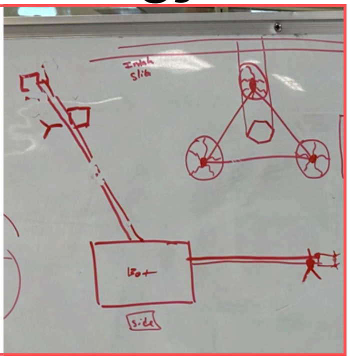
We **value** our mentor's **experiences** and use their **knowledge** to build ours and help us **build our community**.

Our mentors move on to **mentor other teams**, like **Emily Williams**, who went from being a **Beehive FLL Coach** to an **AMES FRC mentor**, and **plans** to **start** an **FTC team** next year.

Design Strategy

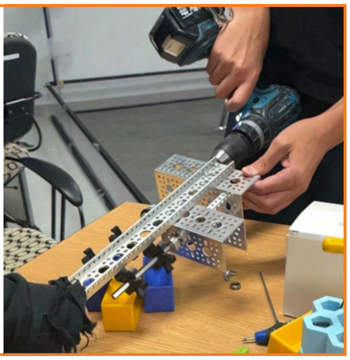
1 Brainstorm

Usually a **drawing** or **schematic**, we host large **brainstorming sessions**, where **everyone** on the team individually **brainstorms**, then shares ideas with each other. Brainstorming is meant to **get ideas out to the table** to **test with** a **prototype**.



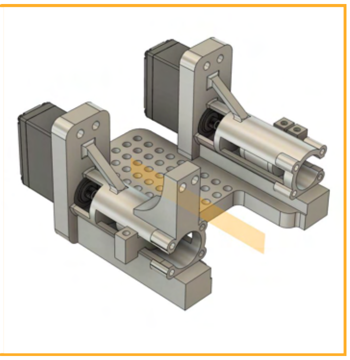
2 Prototype

A prototype includes **free-built mechanisms** mainly built with **COTS** parts or **Fail Fast 3D-Printed** parts. The goal for a prototype is to see **how** a mechanism can **work** with the **rest of the robot** and to **prove** that the **idea works** and to **set** a **basis** for **CAD**, giving us a floor to work from.



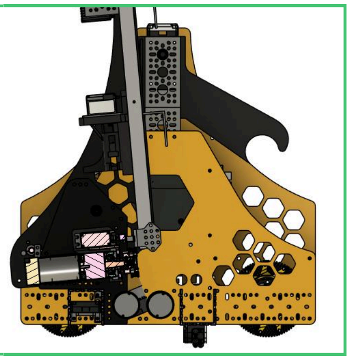
3 CAD

One of our **main design goals** this year was to **CAD before we build**. Designing mechanisms in CAD isn't just good practice, it **allows us to fix problems before the parts are manufactured**. We can also see how **different subsystems work** along with each other.



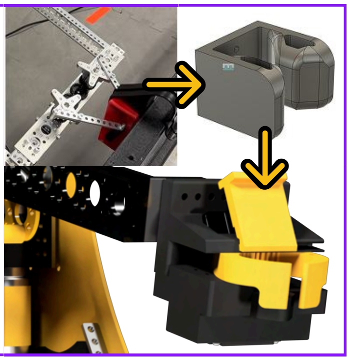
4 Test

We believe in **Test Driven Development**, a **philosophy** where while developing a mechanism, you **rigorously test it to it's limits**. If a **mechanism isn't consistent under our tests**, it needs to be **reworked**. **Reliability** within our mechanisms is **crucial for success**.



5 Iterate

Using what we've learned from our design steps, we'll **iterate on a mechanism until it meets our needs**. Sometimes, this requires to go back to brainstorming. Other times, it's a slight change in the CAD. Either way, **this step is crucial for a consistent robot**.



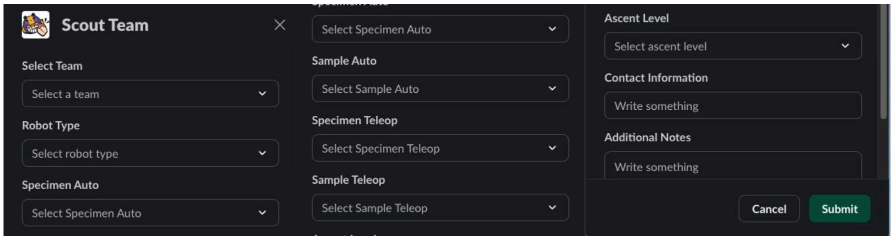
Game Strategy

***Our Goal:* A Consistent Robot that can do both Specimen and Samples -** At the beginning of the year, we decided to make a **robot** that can **efficiently and consistently** score **Specimens** and **Samples**, as well as achieve **endgame** tasks. We knew that we would be a **better alliance partner** if we could be **flexible** to our **alliance's needs**, and **fill any gaps** in our match.

We knew that this decision would come with **tradeoffs**, like not having a 6 Specimen autonomous, but **we decided** that these **tradeoffs would be worth it**.

Scouting Spreadsheet & Match Predictor

Scouting Spreadsheet & Match Predictor - We made a **Slack workflow** that allows us to **scout each team beforehand**. Using our scouting and statistics on FTCScout, we've **developed a formula** to **predict** matches. This allows us to **strategize before each match** and predict our wins & losses.



Match Predictor (with peak OPR)

Blue Alliance				VS		Red Alliance			
21336		21336				3747		3747	
Spec Score	Sample Score	Spec Score	Sample Score			Spec Score	Sample Score	Spec Score	Sample Score
195.09	194.76	195.09	194.76			130.395	133.42	130.395	133.42
Specimen	Sample	Specimen	Sample	59.66%	40.34%	Specimen	Sample	Specimen	Sample
☑	☐	☑	☐			☐	☑	☑	☐
Predicted Score				tossup		Predicted Score			
Team 1			195.09			Team 1			133.42
Team 2			195.09			Team 2			130.395
Estimated Score			390.18			Estimated Score			263.815

Offensive Contribution - The "offensive" points a team will score in a given match.
Defensive Contribution - A measure of the points a team prevents from the other alliance from scoring using defensive measures.

Defense

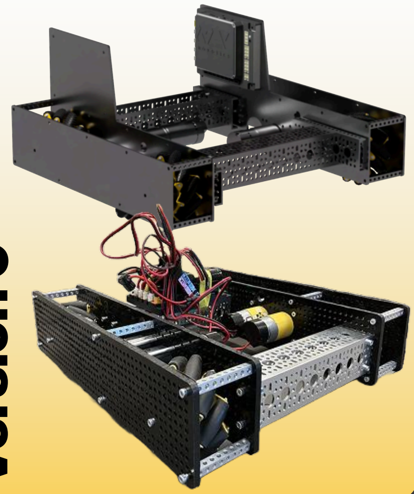
Defense - Based on our scouting, we've strategized 4 levels of defense, which we decide to use on a per-match basis.

1. **Pure Cycling:** This strategy is based around maximizing our Offensive Contribution, where we maximize cycles and minimize time spent at sub.
2. **Light Defense:** Similar to Pure Cycling, but with some contact at sub. Very offensive, but it has a little bit of defense as well. This is our most used strategy, as it maximize Offensive & Defensive Contribution.
3. **Aggressive Defense:** Prioritizing Defensive Contribution, this strategy is much more aggressive than others. For every ~10 seconds we delay the opposing alliance, we'll contribute one cycle.
4. **Lockdown Defense:** Completely ignoring Offensive Contribution, this strategy is a last-resort meant for matches that have been pre-determined to otherwise be a loss.

KEY	
Green	Positive Attribute
Yellow	Lesson Learned
Red	Negative Attribute

Basic Parallel Plate Drivetrain / Offseason

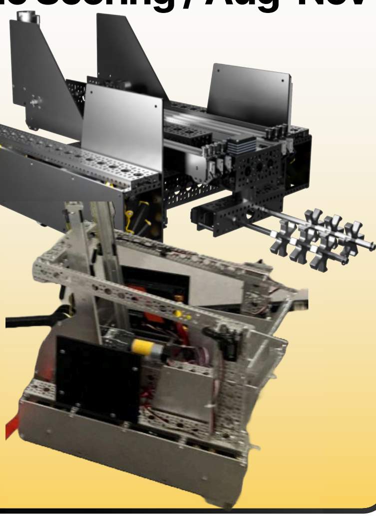
Version 0



- Parallel Plate Drivetrain is faster than a COTS Strafer Drivetrain
- Central Motor Packaging allows for a lower and more central Center of Mass
- Learning how to manufacture custom plates
- Belt Tension must be precise to prevent slippage
- Polycarbonate plates are hard to manufacture and not durable
- Bad Control Hub and battery placement resulted in unsafe wiring and static

Custom Robot With Basic Scoring / Aug-Nov

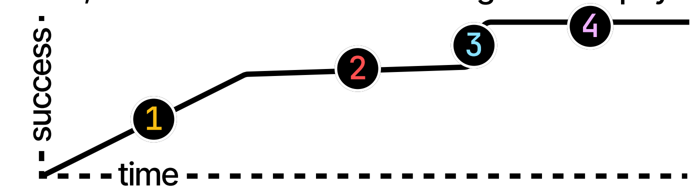
Version 1



- Control Hub Mounting and Wiring is organized and safe
- Pivot has resting stops which allows for power use in other places, saving voltage
- V1 of intake, worked decently well for both intaking and scoring
- Wiring on linear slides needs to be managed properly
- Packaging is difficult when doing Samples and Specimen
- Robot is bland and ugly
- No Ascent mechanism and robot is very heavy
- Strung slides were slow, broke easily, and inconsistent
- Speciarm was bulky, slow, and didn't have proper tolerances

Design Philosophy

Design Philosophy - Through our experiences in robot design, input from mentors, and what we've learned from high-performing teams, we've arrived at a solid Design Philosophy:



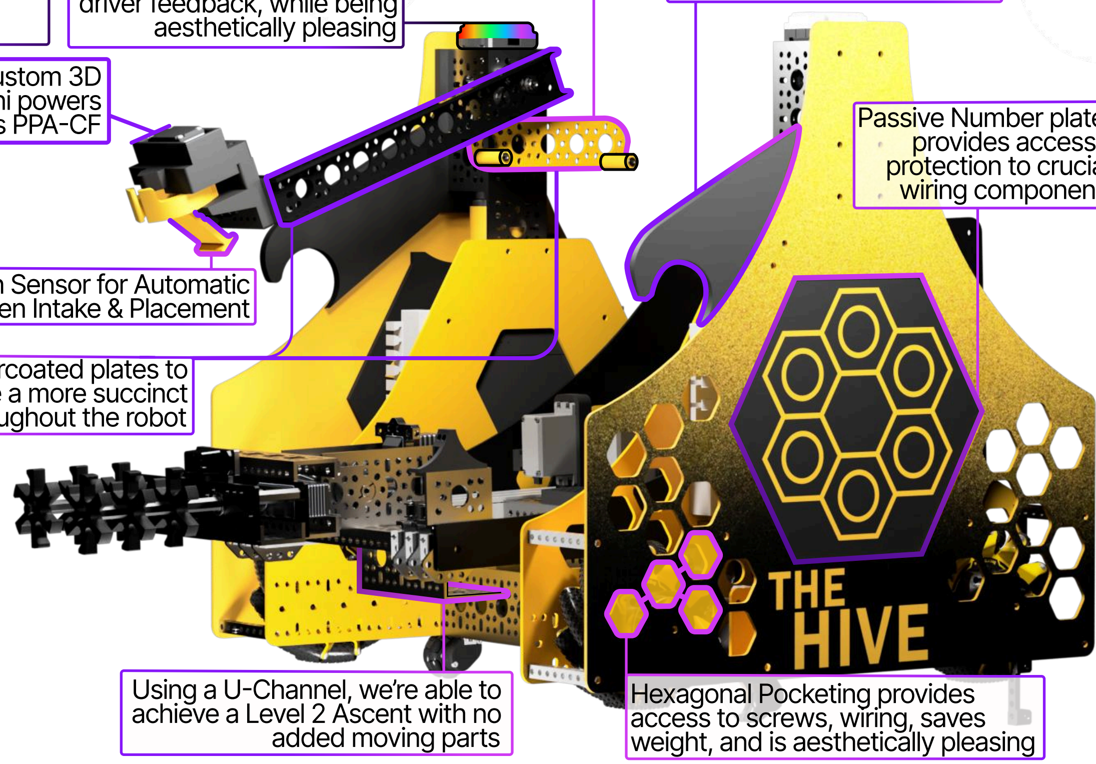
1. Start with a simple design that can achieve our game strategy. This design goes through multiple iterations.
2. Optimize, combining simple actions to accomplish complex tasks. Maximize consistency and speed.
3. Once we hit a plateau, add complexity to our designs to reach the next level of success.
4. Optimize and ensure that this new complexity doesn't interfere with our consistency and strategy.

Meet our robot: Beecon

Why Beecon? - After we built our V2 Robot, we did a blind straw vote to decide on the name. We found that Beecon represents our robot the best, and came up with this:

"Just as a Beecon lights the sea, we light up FTC"

Our robot follows a **yellow** and **black** theme, as we are **The Hive.** The only visible colors on the robot are black, yellow, and bare aluminum, following our team's branding.



Passive stops for Speciarm allow for power saving and protects the robot from itself

Hooks allow for Level 2 Ascent with passive holding, reducing power draw

"Beecons" on both side of robot light up and provide driver feedback, while being aesthetically pleasing

Speciarm Claw with custom 3D Printed gearing, Axon Mini powers the claw, and housing is PPA-CF

Passive Number plates provides access & protection to crucial wiring components

Touch Sensor for Automatic Specimen Intake & Placement

Powdercoated plates to provide a more succinct look throughout the robot

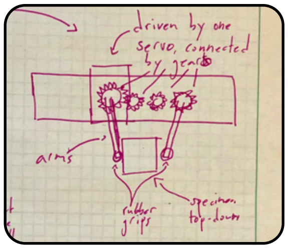
Using a U-Channel, we're able to achieve a Level 2 Ascent with no added moving parts

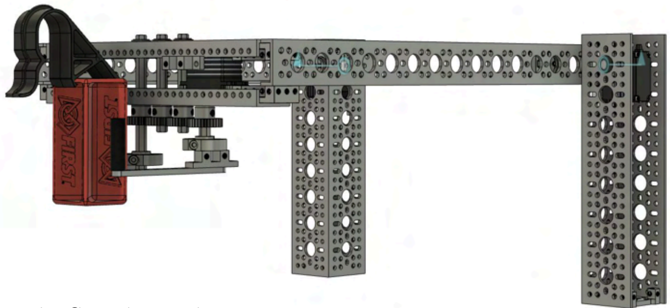
Hexagonal Pocketing provides access to screws, wiring, saves weight, and is aesthetically pleasing

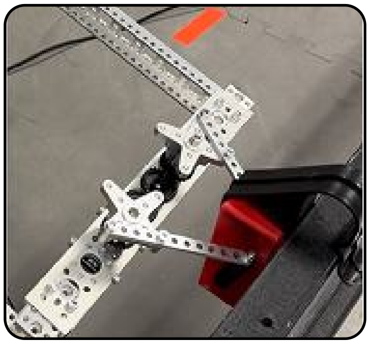
Wiring Cover

We designed the **first-ever** 3D Printable **wiring organizer** meant for **strain relief** and **Control Hub mounting.** Last year, our wiring was **messy**, **unorganized**, and **hard to follow**. One of our **goals** this year was to have **organized** and **tidy wiring**, and this wiring cover meets that goal. All of this is **tucked behind our number plate, providing protection.**

Version 1



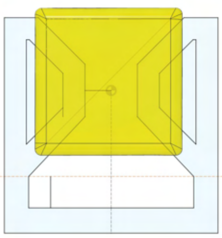


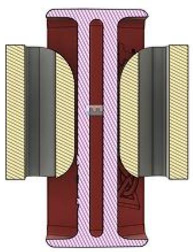


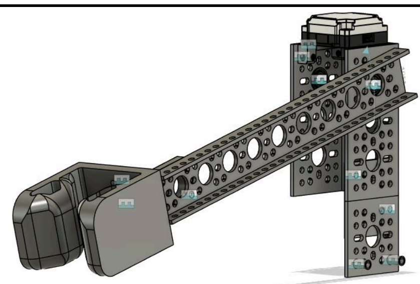
This first iteration was to **serve two purposes**:
1. Act as a physical stop for the pivot
2. Intake and Score Specimen
The **range of motion** was the length of the entire robot, and since it was **bulky**, it **interfered** with the slides and added **unnecessary weight** to the robot.
This iteration was ran by **four servos**, two for the arm and two for the claw, making **programming difficult** and **increasing power draw**.

Lessons Learned
COTS Active Claw →
- Provides more tolerance for driver error, easier to design.
- Stops shouldn't be held in place by another mechanism, they should be part of the chassis.
- Just because a design is easy to build doesn't mean it's simple.
- The first idea you think of isn't always the greatest.
- Takes too much time to close.
- More prog. necessary.
- Power draw is increased.
- More DOF (Degrees of Freedom) → More areas for robot to break, and increased maintenance.

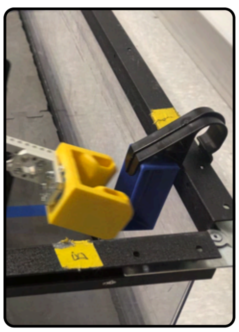
Version 2

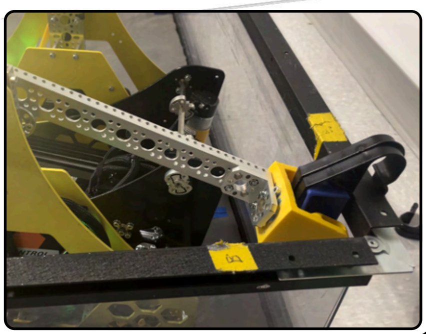






We then had the idea to switch to a **passive claw** using F-PLA. We **started** with a **sketch** and amassed **30+ iterations** in just a few weeks. The claw was designed to easily **grab** the **specimen** and **hold it tightly**, and we used **fillets** in CAD to achieve this.

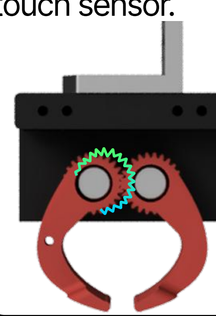


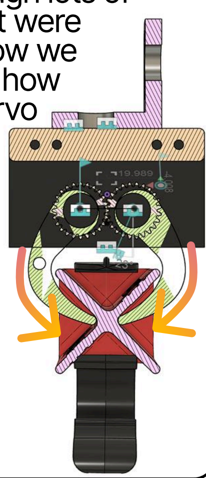


Lessons Learned
Custom 3DP Flexible Claw →
- Singular arm takes up less space and scores better than two arms.
- This design only uses 1 servo, compared to 4 on the previous.
- Barely any programming required.
- Although passive designs are simpler, they may not be better.
- When designing a mechanism, plan for tolerances and changes in the environment.
- Intaking Specimen is extremely inconsistent and difficult.
- Scoring is inconsistent, as it only works properly at our home field and not at competition fields.

Version 3

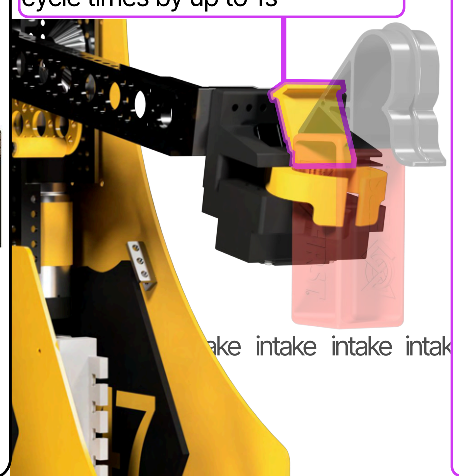
Our final design combined the **best of both worlds**. It uses a **single servo for the claw** and a **high RPM motor for the arm**. The **claw** is **rigid** rather than flexible, and it also has a **touch sensor for automatic intake**. This claw also went through lots of **iterations**, but most were **small tweaks** on how we hold the specimen, how we package the servo & wiring, and the touch sensor.

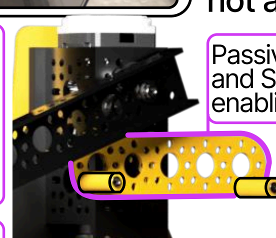




Since we switched to a motor, scoring is near-instant, taking around 500ms to score per cycle. Also, the increased power of the arm "forces" the Specimen on the chamber with more tolerance for spacing.

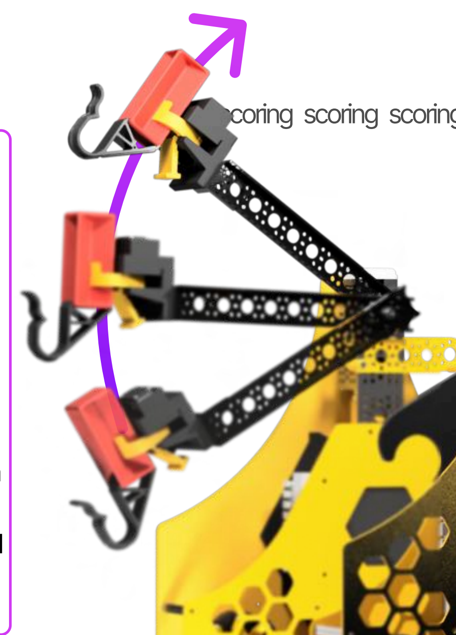
Touch Sensor powers automatic Specimen intake, decreasing our cycle times by up to 1s





Passive stops for the Speciarm at the Collect and Score positions allows us to cut power, enabling more power usage elsewhere.

Testing
Our Speciarm was designed with tolerances in mind. While testing, we changed the height and spacing of the chamber to account for *FIRST*'s tolerance specifications, and ensured that the scoring worked in a variety of environments. When testing, we try intaking from a variety of angles and distances, to ensure accuracy and speed for drivers.

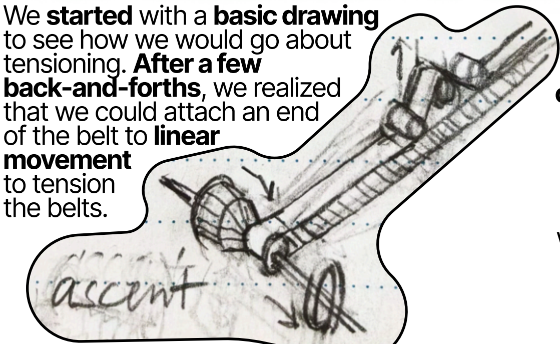


Tensioner

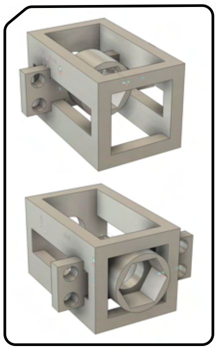
Problem: Belts lost tension over time, resulting in incorrect encoders, loss of speed, and inconsistent scoring.

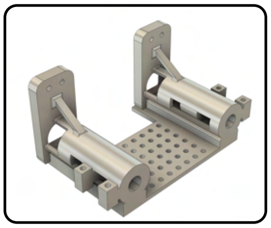
What if we could tension our belts during the match?

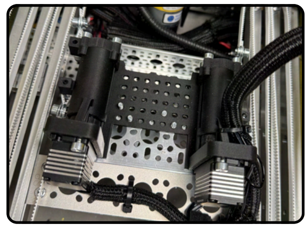
We **started** with a **basic drawing** to see how we would go about tensioning. **After a few back-and-forths**, we realized that we could attach an end of the belt to **linear movement** to tension the belts.



We made a **basic proof-of-concept** in CAD and 3D Printed it. After **confirming that it works**, we **moved on with the design process.**







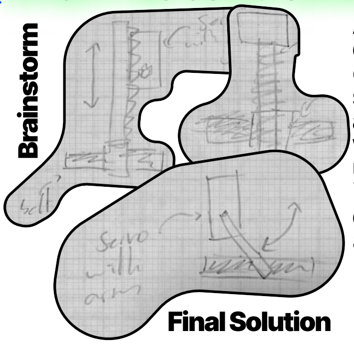
We made a CAD and printed a working tensioner, mounted it to our slides, and tested it. We encountered many unforeseen issues with the tensioner system:

- The way the bolt and nut were held in wasn't strong enough.
- The slides wouldn't close where the tensioner sides were, we had packaging issues.
- The tensioner wasn't fast enough with an Axon Mini.

Derailer

Problem: Consistent Level Two ascent and fast slide extension can't coexist— higher torque pulleys mean a Level 2 Ascent but slower slides, and vice versa.

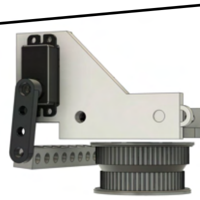
What if we could switch pulley ratios for endgame?



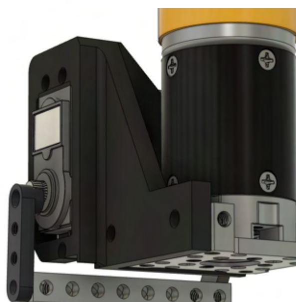
After considering **dozens of ideas**, we came up with a **final solution: a servo with an arm and pulleys, which guides the belt up**. This design is inspired by a **bicycle derailer**, which work in a similar fashion (mechanical arm moves, guiding the belt with it).

Goals for CAD →

- Small and low-power for packaging
- 100% Consistency. The Derailer **cannot** fail.
- Smooth and fast mechanism
- Holds the belts in the correct position normally
- No extra wear to the belts; the derailer can't move the belts far away from their natural path.



Using an **Axon Micro**, this system is simple. We attached **pulleys** to the **bottom of the arm**, and the derailer moved down to **derail** the belts. It attaches around the motor and fits snugly.

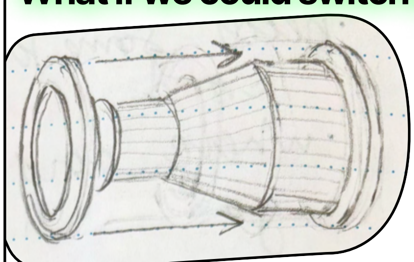


We switched to an **Axon Mini**, due to **reliability issues**. We changed the **mount**, changed the **pulleys** we use, switched to derailing **down → up**, thickened the mount, and **saved** some space.

This design is **100% Consistent**

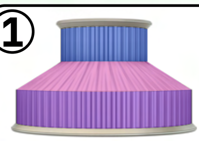
Dual-Ratio Pulley

What if we could switch pulley ratios for endgame?



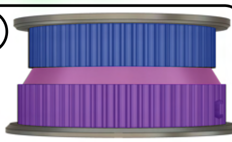
After considering a few different ideas, we settled on this solution: **2 different pulleys** connected together through a toothed cone, allowing for a **seamless transition** for the belt **in-between the two spools.**

1

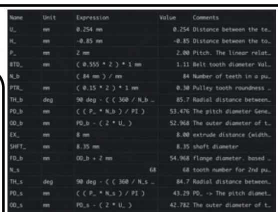


Our initial design was **three stages**, a **geared transition** stage, a **first-stage** (high-rpm), and a **second-stage** (high-torque). We found the belt would sometimes **derail accidentally**.

2



We **changed** the **gear ratios** to be more similar for the **belt** to **transition easier** and removed the teeth from the transition stage. We found the **transition stage** was **unnecessary** due to how **fast** the **derailer** was, and added extra bulkiness.

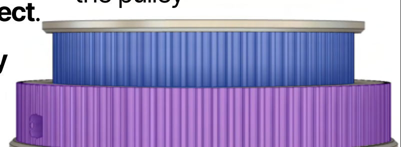


Iterations took **forever**, as we had to **manually design** the **pulleys** each time and found that the **slope** on the **gears** was **incorrect**.

We found a **pulley algorithm** and **customized** and **tested** it for our solution.

After some other iterations and testing, we ended up with this **final design:**

- Specialized gear ratios providing the exact amount of torque needed to ascend
- Sonic Hub embedded to ensure accurate spacing
- Printed in two parts so one damaged gear can be replaced easily
- Flange stops to prevent the belt from falling off of the pulley



Why?
These three designs work together to achieve something **never done before in FTC:**

Switch spool ratios during a match in order to increase torque in slides for a Level 2 Ascent.

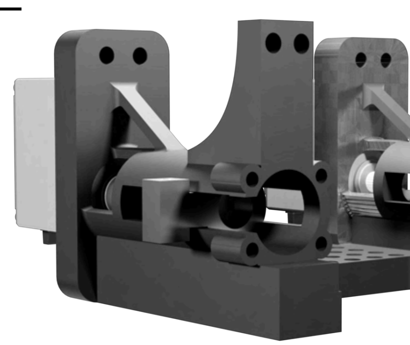
Want a Live Demo? Come to our pit!

This entire mechanism works in 4 automated steps:

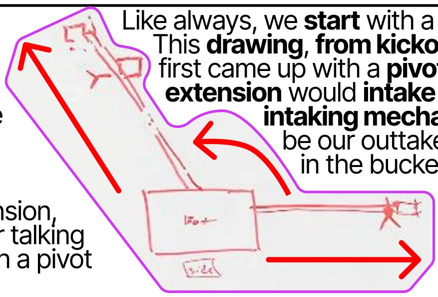
1. The slides extend to prepare for derailment
2. The derailer activates, moving the belts to the other pulley
3. The slides retract, completing the derailment
4. The tensioner passively tensions the slides

This process takes less than 2 seconds!

Tensioner Full CAD



Version 1



Like always, we **start** with a **simple drawing**. This **drawing**, **from kickoff**, was when we first came up with a **pivot**. Our **lateral extension** would **intake** and the same **intaking mechanism** would also be our outtake, **scoring** samples in the bucket.

Why Pivot?

At the beginning of the year, we came up with multiple different archetypes, including Lateral + Vertical extension, turrets, arms, etc. After talking about it, we decided on a pivot for a few reasons:

- **No Transfer:** Last year, we had a very bad experience with transfer consistency.
- **Less Motors:** Without added complexity like a PTO, a Lat. + Vert. Extension design requires 4 motors dedicated to the slides, and a pivot only requires 3 motors.
- **Packaging:** A pivot is a lot less bulky, since you don't need to package 2 sets of slides, their spools, motors, wiring, encoders, etc.

Before We CAD →

When designing a **mechanism** that will be run **thousands of times** and needs to be **100% reliable**, **reducing power use and friction is a must**. When you need to use more power, the motors heat up, causing **damage** to the **mechanism**. This means we need to **find the optimal pivot placement using math.** →

Finding Optimal Pivot Placement using Math

Goals for Math →

- Find optimal pivot placement that requires the least amount of Work for motors to pivot slides, while maximizing speeds.
- Find optimal pivot motor, accounting for torque needed to move the slide mechanism.
- Reduce voltage used for slides, in order to allow for simultaneous actions, like driving, pivoting, and extending at the same time.

This page is a summary of our math, come to our pit to see more!

We can start by using the definition of Inertia, $I=mr^2$

We then set up the equation for the mechanisms we know are going to be on the slides:

$$I_s = \underbrace{m_m r_m^2}_{\text{motors}} + \underbrace{m_p r_p^2}_{\text{plates}} + \underbrace{m_s r_s^2}_{\text{slides}} + \underbrace{m_i r_i^2}_{\text{intake}}$$

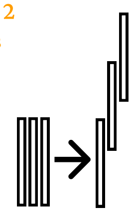
These never change

These are dynamic based on slide extension

Solving for $m_s r_s^2$

Never Changes

This Changes



Length of Slides Equation:

$$f(E) = L+E(n-1)$$

n → number of slides
L → length of slides
E → extension length
M → mass of a single slide

Putting that all together we get:

$$I_s = m_m r_m^2 + m_p r_p^2 + nM\left(\frac{L+E(n-1)}{2}+C\right)^2 + m_i\left(L+E(n-1)+C+r_i\right)^2$$

Solving for torque:

τ → torque of motor
I → moment of inertia
α → acceleration

$$\tau = I\alpha$$

Solving for acceleration:

$$\alpha = \frac{\tau}{I}$$

torque of motors

inertia of system

acceleration of slides

Because slides are equal length, the Center of Mass is in the middle of the system.

$$r_s = \left(\frac{L+E(n-1)}{2}+C\right)$$

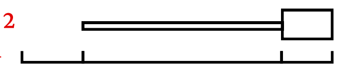
C → dist from the bottom slide to the fulcrum

$$m_s = nM$$

Solving for $m_i r_i^2$

Never Changes

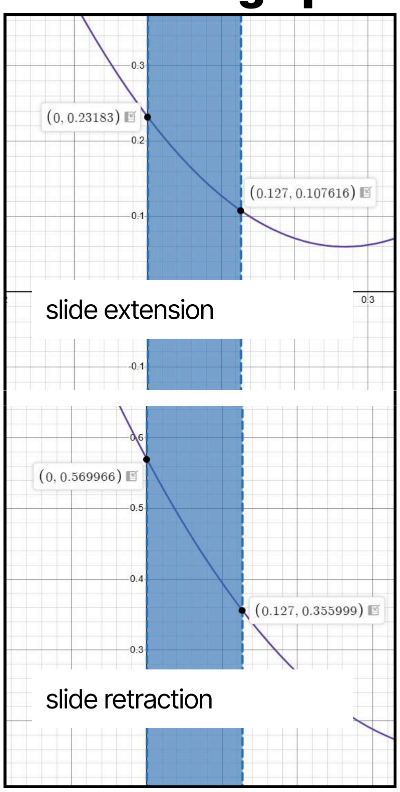
This Changes



Distance from fulcrum is dependent on E (extension)

$$r_i = L+E(n-1) + C + r_i$$

Now we can graph it!



Testing Motor Torques

Highest moment of inertia:
0.569 kg.m2
Lowest moment of inertia:
0.107 kg.m2
Chosen Pivot Location:
0.404 kg.m2

Conclusion:
The 60 RPM motor still provides enough torque to move the module, but is much faster than the 30 or 45 RPM motors.

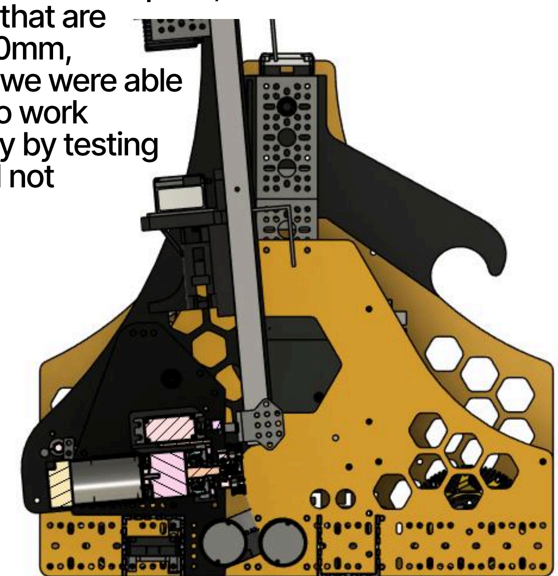
Passive Stops for Power Optimization

At our pivot's low and high points there are passive stops which enable more power usage elsewhere. Using our built-in pivot encoder, we are able to detect when we are at a stop and change the motor behavior to reduce the power usage.

Want a Live Demo? Come to our pit!

Accounting for Tolerances and Interferences

When designing multiple subsystems on a robot, ensuring that they work together is a necessity. We design different subsystems in different files and combine them in a full assembly to test for interferences. On our pivot, there are some tolerances that are less than 10mm, tolerances we were able to ensure to work consistently by testing in CAD and not in-person.



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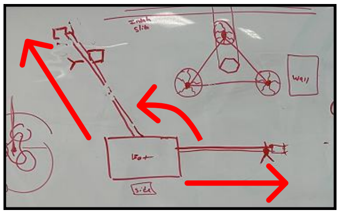
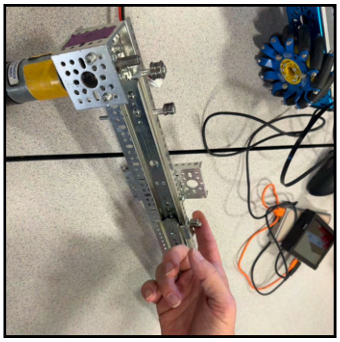
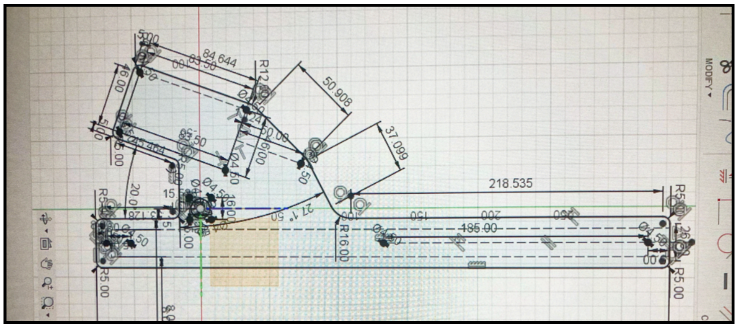
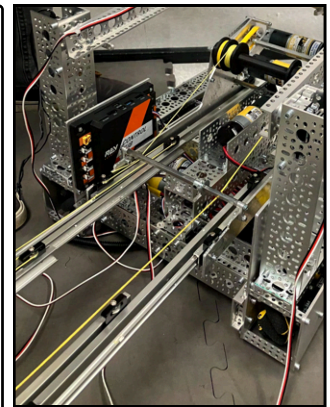
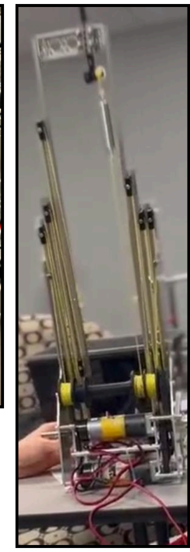






Starting with a basic Proof-Of-Concept, then CAD.
This is our first year using Misumi linear slides, and during brainstorming we determined that slides would be the best strategy. We started with a basic Proof-Of-Concept, then moved on to CAD.





Using plates we manufactured with the help of FRC 4598, we manufactured and tested a basic slide prototype. **There was a *lot* to improve.**

Lessons Learned

Slides With Rope →

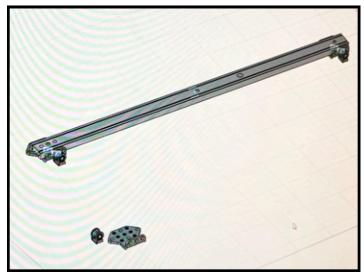
- Have the potential to be faster and more consistent than belted slides.
- We have a mentor who specializes in rope who can help us acquire the proper durable rope for slides.
- Stringing and tensioning slides with Rope is much more difficult and time-consuming than belted slides.
- High-level slides require previous knowledge and experience, which we lack.

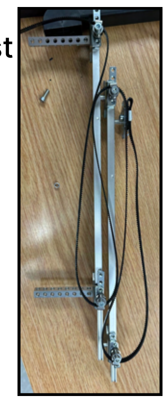
After learning from teams that are experienced in using slides, like 5026 Tesla Coils, we determined that belted slides would be our best option this year.

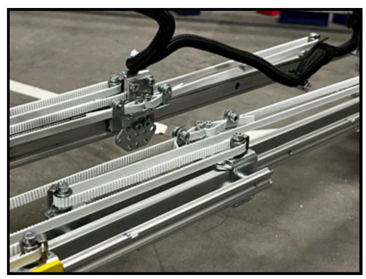
Version 2

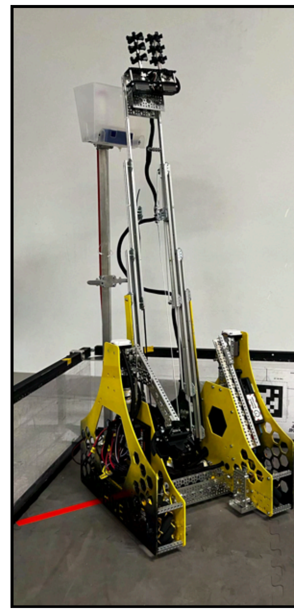
Using Misumi Slides and GoBilda Viper Belt inserts (pictured on the right →), we were able to quickly prototype, design, and test a belted slide mechanism.

Belted slides are consistent, easy to install and repair, and easy to program.







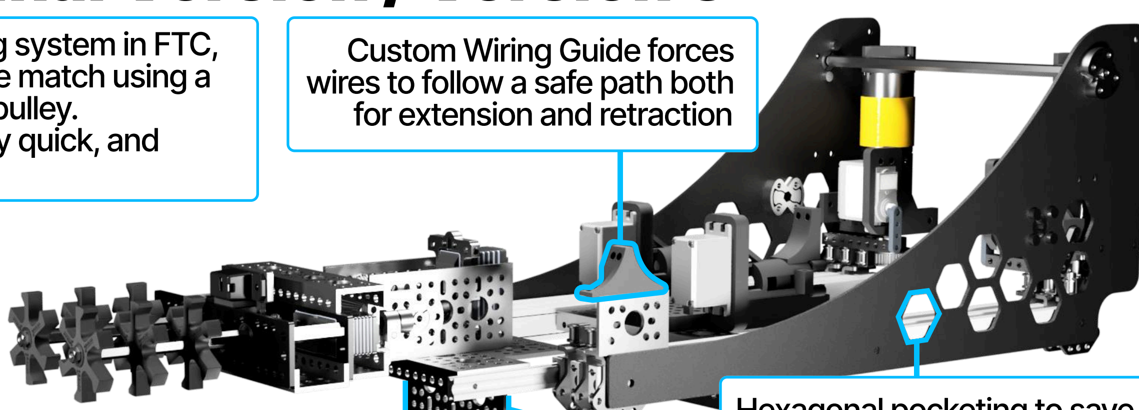


Want a Live Demo? Come to our pit!

Final Version / Version 3

Slides use the first-ever derailing system in FTC, switching pulley ratios during the match using a derailer, tensioner, and 2-stage pulley. Transition is seamless, extremely quick, and 100% consistent.

Custom Wiring Guide forces wires to follow a safe path both for extension and retraction



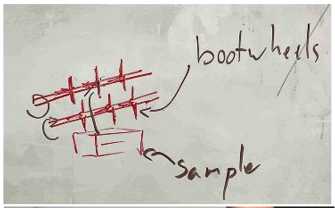
Belted slides are consistent, easy to maintain, and robust, maximizing our efficiency and use over time.

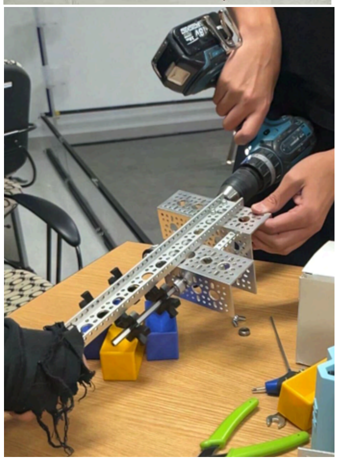
Slides extend up to 4' in length, but have software locks to stay legal.

Hook for Level Two Ascent

Hexagonal pocketing to save weight and provide access to screws & parts

Version 1





Initial Testing

pickup speed test	pickup time	time angle	time angle	average
level: 435	0.05 secs	0.2 secs	0.27 secs	0.173334 secs
level: 117	0.58 secs	0.25 secs	0.94 secs	0.59 secs
level: 1,620	really fast, but can't take pieces in consistently			
level: 312	0.18 secs	0.34 secs	0.22 secs	
level: 6,000	so fast that it immediately breaks the robot, I don't kn			
level: 30	2.68	1.74	1.84	
level: 45	0.83	0.87	1.22	

In the design process, testing is the most important step. In intakes, testing is the *first* step (after brainstorming). This way, we're able to CAD and build versions using an intake that already works well, and improve it even more.

Why a top-down active?

We **determined** that a **claw wouldn't be effective without** proper **Camera Vision,** and **top-down** intake could be **temporary** until we get CV working. Ultimately, we stuck with actives because they outperformed claws.

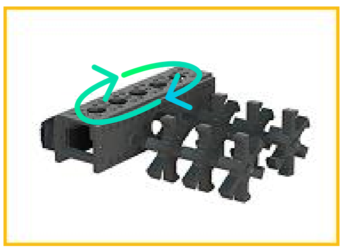
Lessons Learned

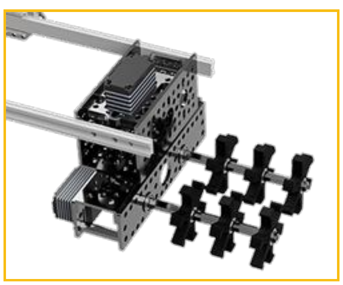
Fast RPM →
Flings sample out of intake.
Slow RPM →
Takes longer to intake and misses samples at bad angles.

More Wheels →
Too adherent to sample, shoots out too hard. Less tolerance for different angles.
Less Wheels →
Not adherent enough, misses samples at various angles.

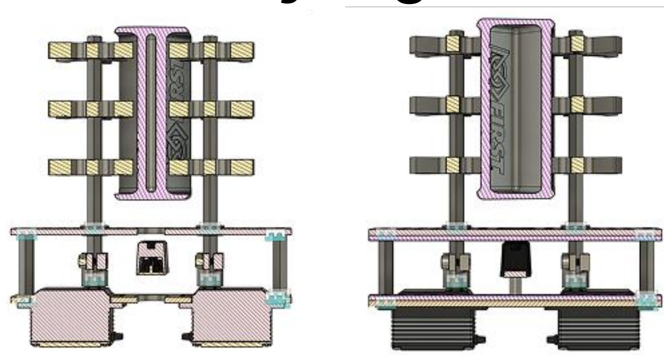
Just Perfect →
Can consistently intake from most angles, intakes quickly and is "touch-and-own."

Version 2





Sim. & Analyzing in CAD



By simulating and analyzing our intake in CAD, we were able to perfect our spacing, and make the most optimal intake within CAD, without any physical prototypes.

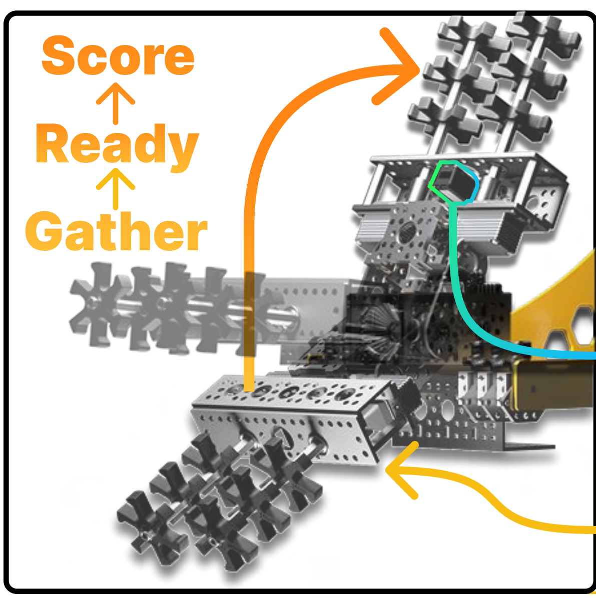
Rotation vs Pivot

Originally, we started with a horizontal rotation.

After testing, we decided to experiment with a vertical pivot, CADding and building the pivot in just *one day*.

Another benefit of the pivot is the **decreased power draw**, as we no longer have to use the slide pivot to enter the submersible.

Final Version / Version 3



Wrist pivots up to stow/ place, preventing missed samples and moving out of the way.

Color sensor allows for semi-automated intake, pivoting back up once it detects correct sample.

Wrist pivots down to intake samples, intaking at an angle.

- **Raising the slide assembly no longer necessary to enter submersible.**
- **Pivot intakes most samples faster at an angle.**
- **Angled down Color Sensor sees samples faster.**
- **Intake is "touch-and-own", allowing us to grab samples in most orientations.**

Control Strategy

Use automation to link simple actions in clever ways to accomplish complex tasks and increase the robustness and reliability of components.

Problem: Autonomous Pathing

Solution V1: RoadRunner

Using **GoBilda Pinpoint** Odometry & two 4-Bar Odo. Pods, we learned **RR Actions**, and tuned and wrote **consistent** 4 Sample (64Pt) and 3 Spec. (60Pt) autons.

Problem: Hit Speed Plateau

Solution V2: PedroPathing, FTCLib

Connecting with the PedroPathing developers, we were able to quickly make the switch from RoadRunner to PedroPathing in **just one week.**

Problem: Inconsistencies

Solution V3: Custom Pathing + Pedro

By using **custom** FTCLib **Commands** we **directly power wheels** to ensure accurate alignment on field elements with **differing tolerances**. This **avoids delays** that occur because the pathing cannot reach an exact point due to field variability. We also **use sensors** like the **Touch Sensor** on our Speciarm Claw and the **Color Sensor** on our Intake in order to **end paths early and save time.**

Autonomous Consistency

Learning RoadRunner

1/24 Sample | 64 Points; Specimen | 60 Points

V3 rebuild finished

Learning PedroPathing

2/14 Sample | 0 Points; Specimen | 100 Points

switch from RR to Pedro

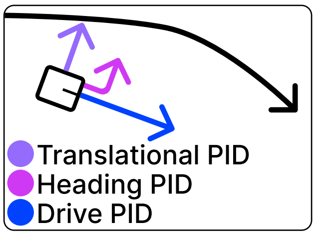
Custom Pathing + Pedro

3/1 Sample | 64 Points; Specimen | 100 Points

using sensors and timeouts

Sensor + Timeout Failsafes

Now Sample | 64 Points; Specimen | 100 Points



PedroPathing is a **Bezier-Based Reactive Vector follower**. Using 3 different individualized PIDs, it corrects during the path, allowing for the robot to run at a higher speed.

"Smart" Autonomous with Fail-safes

Using FTCLib Commands, we have a "smart" autonomous that uses multiple sensors and timers to end paths early and use fail-safes.

:00 Follow Preload Path - Speciarm → Enter - Pivot → Up

After Score Follow Push Samples Path - Start Timer in Race

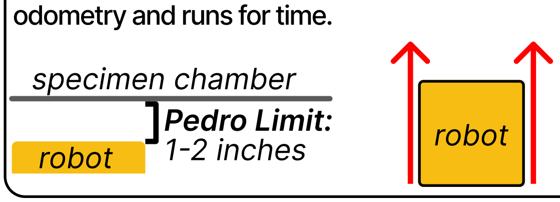
if Touch sensor pressed - Claw → Close → Score Spec

if Time Limit Passed - Skip Scoring → Go to next path

if Path is Done - Claw → Close → Score Spec

Raw Drive Accounting for Tolerances

PedroPathing's tolerances aren't enough for field tolerances. This causes us to miss scoring Specimen on occasion. So, we created a custom Drive forward command which ignores odometry and runs for time.



Raw Drive drives straight for 500ms before scoring.

Using Sensors in Autonomous

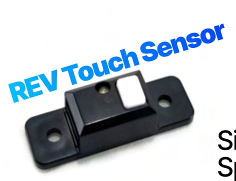
The more sensors there are, the higher chance there is for a successful autonomous. Increasing inputs results in a more consistent and accurate outputs.

Intaking Sample - Start Timer in Race

if Intake Detects Sample → Score Sample

if Time Limit Passed → Score Sample

Using the Color Sensor on the intake, we are able to stop our intake if there is a sample in the intake.



Intaking Specimen - Start Timer in Race

if Touch Sensor Pressed → Score Specimen

if Time Limit Passed → Score Specimen

Similar to the Color Sensor, the Touch Sensor on the Speciarm Claw allows us to instantly score if we detect a Specimen.

Increasing Consistency

For a successful robot game, our autonomous has to be extremely consistent. Our autonomous programming is built to have multiple fail-safes and our mechanisms are built to accommodate different tolerances.

An example of this is our Specimen Autonomous, which has multiple fail-safes for each path to ensure consistency.

Prog. Conventions
Variables start lowercase and are Camel Case nouns.
Classes start uppercase and are Camel Case nouns.
Functions start lowercase and are Camel Case verbs.
No Global Variables allowed.
No backwards references to parent classes unless for enumerated type, avoiding circular control problems.
Grouping of all class variables & constants at the beginning of class.
Grouping of all functions together & according to similar function.
Grouping of all inner classes together.

Field Orientation Reset

Slow Mode
Hold button for reduced driver speed for fine adjustment.

Controller Dead Zones
Slight offsets of the joystick from a cardinal position are ignored until a threshold is exceeded.

Driver Feedback
During the match, we use our two lights (beacons) in order to give drivers feedback and information on the current status of the robot and the match.

- Config Mode turned on
- All motors were Zeroed (Config Mode)
- Endgame Warning
- Hang Mode Activated
- Autonomous hanging sequence in-progress
- Derail Activated
- Hang Mode Confirmation Sequence
- Extending slides with no limits
- Spec Claw activated WITH Touch Sensor
- Spec Claw activated MANUALLY
- Intaking Sample
- Normal Gameplay

Four Different TeleOp Modes

1 Config Mode
The purpose of this mode is to provide a way to reset certain "knowns" without having to stop TeleOp. An example of this is motor zeroes. If a problem were to occur in Autonomous, and we have the incorrect motor zeroes for TeleOp, then the drivers are quickly able to reset the zeroes of any motor they choose. They can also reset the zeroes of the entire robot.

2 Regular TeleOp

3 Derail Mode
At some point during TeleOp, we need to derail the slides and switch the spool ratio for endgame. The derail mode does that, completely autonomously.

4 Hang Mode
This mode is meant purely for when you are going to hang and no other times.

Completely Autonomous Derail
Using FTC Lib Commands during TeleOp, the drivers are able to derail at any point in the match. The derail is completely autonomous and is extremely quick.

Gamepad 2 DPAD Down
↓
Any Other Button → Return to regular TeleOp
Gamepad 2 DPAD Down → Activate Derail Mode

if Derail Mode Activated AND Robot Hasn't Derailed

Restricted Slide Controls:
- Extend Slides — Extends to max legal extension
- Derail Belt — Changes the state of the derailer
- Retract Slides — Retracts using its current position rather than an incorrect encoder read

↓
Start Tensioning · Start Timer · Activate Hang Mode
if Time Limit Passed · Stop Tensioning

No Magic Numbers
All "unchangeable" variables are written in snake case, such as SLIDE_HEIGHT_MAX_TICKS.

No Loops
No loops within the Critical loop.
Actions are started and monitored each loop to chain a next action using a signal, (Position, time, sensor).

Completely Autonomous Ascent
Using Switch → Case, we are able to achieve a Level Two Ascent with **zero** driver input. All the driver needs to do is line the robot up, click a button, and the robot will ascend autonomously.

MUST BE IN HANG MODE TO HANG

Switch
- State -1: Robot is allowed to drive freely
- State 0: Zero Slide Motors ⟶ Pivot → Up · Wrist → Stow · Speciarm → Collect
  - Start Timer · if Time Limit Passed · State → 1
- State 1: Extend Slides ⟶ if Extension Reached · Hold Slides
  - Start Timer · if Time Limit Passed · State → 2
- State 2: Drop Pivot · Start Timer · if Time Limit Passed · State → 3
- State 3: Raw Drive Backward · Slow Extend Slides
  - Start Timer · if Time Limit Passed · State → 4
- State 4: Pivot Down · Retract Slides Full Power
  - Start Timer · if Time Limit 1 Passed · Tip Pivot onto Bar
  - if Time Limit 2 Passed · State → 5
- State 5: Release Pivot