
MakEMinds
23786
FIRST
MakEMinds Robotics
2024-2025 | INTO THE DEEP
ENGINEERING PORTFOLIO
23786

Executive Summary

Long Term Goals

- **Create** simple robots that effectively complete design tasks, only adding complexity when it provides an advantage
- **Take** our outreach international, aiding teams in other countries and promoting FIRST worldwide
- **Develop** member sustainability resources to ensure that knowledge is not lost when alumni leave
- **Develop** aesthetic robots that do not lack functionality
- **Ensure** that our team functions smoothly, adhering to deadlines to ensure that we do not rush anything last-minute
- **Adhere to our mission:** Have fun, raise STEM awareness, and build a robot to do impossible things!

Season Timeline:

August	September	October	November	December	January	February	March

💻 Prepare basic code & train new members
🔧 Build linear slides & train team
⭐ +3 Outreach

💻 Develop controls & test auto
🔧 Build basic robot
⭐ +2 Sponsors

💻 Creating perfect autonomous routines and paths
🔧 Scout and start building new robot
⭐ 10/26 Q1

💻 Develop new skills (PedroPathing, PID)
🔧 Build & compare new design
⭐ +1 Sponsor

💻 Scouting, portfolio & auto tuning
🔧 Refine design into effective robot
⭐ 12/13 Q2

💻 Tune & perfect auto routines
🔧 Rebuild end effector & wire management
⭐ 1/18 Q3

💻 Incorporate PID & recode
🔧 Update portfolio and scouting
⭐ +2 Outreach

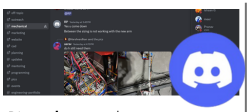
💻 Perfect interview & driver practice
🔧 Autonomous perfection

📊 By the Numbers:

🏆**6** Outreach Events | 🤖 **3** Robot Designs | 💻 **3** New Programming Concepts Learned
👥 **6** New Members Fully Trained | 💰 **3** New Large Sponsors

Organization and Communication

Notion was used to organize our meeting dates and the highlights of those meetings.



Discord was used to manage updates for tasks and have a virtual way to maintain communication throughout the team.

Google associated apps, such as google docs, slides, drive, and sheets were used to organize and store information, as well as divide responsibility equally.

Team Info

This year, we added 6 new members and 4 mentors, totaling 11 members, 2 coaches, and 8 mentors.

Achievements:
Qualifier 1 (10/26). 2nd Place Overall (Highest Score)
Qualifier 2 (12/14). 2nd Place Overall (2nd Highest Score)
Qualifier 3 (1/18). 2nd Place Innovate

Short-Term Goals:

1. Host outreach events and inspire more people about STEM and FIRST.
2. Reach out to others and grow our audience through social media.
3. Modify the claw to make specimen/sample collection more efficient.

MakEMinds Robotics was established in 2023 and represents Edison, NJ.

We compete as Team #23786 and represent Edison Township in the Upper Central League.

Our goal is to educate our community about the principles of robotics.

We have gained 6 new members since our inception, all of which have joined this season.

Team Members

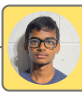
Coaches

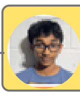
Kirti	Rohit


Meer
Co-Captain
Programming lead
coded the robot


Ishaan
Programming Team
Helped code the autonomous


Harshvardhan
Co-Captain
Mechanical lead
Built the robot and made design changes


Arjun
Mechanical Team
Helped build, rig, and maintain linear slide


Akhil
Mechanical Team
installed localization and managed wiring

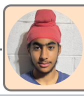

Arya
Design Lead
Cadded design changes before building


Yashvir
Design Team
Iterated on designs in CAD before production


Pranav
Marketing Lead
created reference material and interacted with sponsors


Ritika
Marketing Team
Created marketing material and maintained a portfolio outline


Aarav
Outreach Lead
Implemented outreach ideas and interacted with communities


Jasvin
Outreach Team
Created outreach material

Our team values mentorship, with experienced members on the left, training newcomers on the right, through hands-on learning. Rookies gained skills by coding, designing, building, and collaborating, ensuring a strong foundation for future seasons.

Outreach

FTC and FLL Mentoring

Our team mentored **5 FLL teams**, with **two winning awards** for Innovation and Engineering Excellence. We dedicated **300+ hours** to mentoring, helped FTC team **BetterBot7** start their journey, and assisted **Distractors.exe** with programming.

By the Numbers

5 FLL Teams - 300+ Hours
2 FTC Teams Mentored & Assisted
6 Outreach Events
2300+ Non-FIRST affiliated individuals reached
Taught 9 teams about Engineering portfolio and Interview

Coding Summer Course

Meeting method: Virtual
Advertising method: mass emails + word of mouth
 # people reached: 60 kids attended
% turnout from those advertised to: 63%
Event Description: We offered students in grades 5-8 a 4-day coding course covering Python, Java, and FIRST, where they primarily learned to write and debug their own programs.

Lessons learned:

- General email marketing is not effective
  - Solution: target more specific groups
- Virtual connections prevents efficient solving of technical problems
  - Solution: host an inperson event

Community Center Outreach

Meeting method: In-person
Advertising method: Local Whatsapp Groups
people reached: 45 kids attended
% turnout from those advertised to: 90%
Event Description: A FIRST-themed event for middle and elementary school children, featuring a presentation on our team and the basics of FIRST. Kids had the chance to drive our robot, code FLL Robots, and compete for a small non-monetary prize.

Lesson learned:

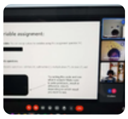
- Fewer interactions at an event reduce its impact on students.
  - Solution: Attend events with more attractions and add activities to boost engagement.

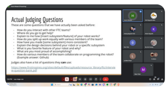
South River Outreach

Meeting method: In-person
Advertising method: Hindu students attending event
people reached: approximately 1200 kids
% turnout from those advertised to: 71%
Event Description: Our team hosted an outreach event to inspire students and parents about STEM and FIRST, showcasing our robot's capabilities and sparking interest in robotics while helping parents understand our work.

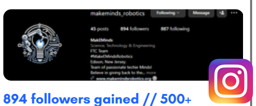
Lesson learned:

- Larger audiences means that not everyone can be reached if we are in one small area
  - Solution: in the future, physically spread ourselves throughout.





Social Media



894 followers gained // 500+ likes 45 posts

We use **Instagram** to share our events with other communities, and have reached nearly **900** individuals.

Hackathon

Meeting method: Virtual
Advertising method: Hackathon Devpost
people reached: 115 attendees
Date: Rescheduled to the third week of February

QIQ Outreach

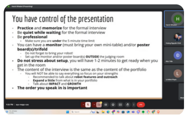
Meeting method: In-person
How many people reached: 35 attendees
Event Description: We taught kids how to program Lego Spike Prime robots. We made practice missions they can do to practice.

Vietnam Outreach

Country: Vietnam

Number of Teams: 9 Teams

- Event: Virtual campaign mentoring Vietnamese teams
- Focus: Portfolio design for FIRST competitions
- Impact: Strengthened global connections



Marketing and Impact

Taksh Foundation

Our team embodies FIRST values by partnering with Taksh Foundation to make STEM accessible to underprivileged students. Through strategic outreach and resource distribution, we foster education equity, engage new communities, and inspire future innovators.

LET IT WAG

We held a fundraiser for Let It Wag outside PetSmart, raising $185 over the course of 2 weekends.

E.M.E.R.G.E

EMERGE was founded by FRC team 2554 and FTC team MakEMinds as a robotics "student council" for local teams. It was created to encourage collaboration and strengthen the robotics community in the Edison-Metuchen area. The initiative aims to organize outreach events and, eventually, offseason competitions.

Our ChatBot shared via newsletter

- We developed a chatbot designed to assist team members in searching for information on the game and on programming.
- It is being offered to the FTCNJ community with the intent of helping with specific game inquiries, such as the height of a basket; or comprehending complex coding concepts.
- While FTCNJ is not officially testing or endorsing it, our FTA did check it out with a few inserted questions and it "got them right".

Sponsorships

1 Preparing for Sponsors
1. Maintain previous sponsorships
2. Get new local and non-local sponsors
3. Maintain constant contact with every sponsor

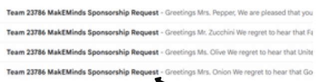
2 In-person marketing to local stores.
- Gained 3 local sponsors
- Cons:
  - sponsorships were all below $250
  - marketing was quite slow

3 Email marketing to large companies
Gained 2 sponsors after writing individual emails to 26 companies
Cons: individually writing each sponsor a personalized email takes a lot of time

4 Standardized marketing to multiple companies
Gained 1 sponsor **and counting**
We made a Google Apps Script to automate sponsor emails via Google Sheets, also being able to send emails thanking them for taking the time to consider us as a sponsee.

Marketing

This season, we experimented with multiple forms of marketing and have developed multiple resources to help us market to individuals and entities beyond FIRST. These scripts help automate emails and make them compelling for companies when asking for sponsorships.


Team 23786 MakEMinds Sponsorship Request - Greetings Mrs. Pepper, We are pleased that you
Team 23786 MakEMinds Sponsorship Request - Greetings Mr. Zucchini We regret to hear that F
Team 23786 MakEMinds Sponsorship Request - Greetings Ms. Olive We regret to hear that Unite
Team 23786 MakEMinds Sponsorship Request - Greetings Mrs. Onion We regret to hear that Go

Testing Data and Results

We also met with the mayor of our town, Sam Joshi who was interested in our accomplishments and we displayed our robot and accomplishments. We also talked about how to spread STEM awareness. We were shouted out in the Edison Newsletter.

Sustainability

Sustainability ensures that our team is able to maintain and improve it's success well into the future, develop team projects and to have a positive impact on the STEM community. Building a sustainable team starts with these 2 foundations: passionate human resources, and financial stability.

Human Resources

Recruiting the next Generation

Annual recruitment period: First week of June
Goals: Attract, enroll, and train new members
Two sections:

- Business
- Technical

Advancement: Members progress in the team's hierarchy every season

Training new members

- **Objective:** Guide freshmen members towards FIRST values and STEM disciplines
- **Focus:** Teach juniors about FTC (FIRST Tech Challenge)
- **Hands-on experience:** Encourage building robots and mechanisms using 3D printed and COTS components
- **Competition:** Held in August to test efficiency, simplicity, and robustness of designs

Example slide for building basic knowledge

Developing sustainability resources

- **Current situation:** No seniors on the team this season
- **Future concern:** Impact of graduating members on team knowledge
- **Long-term goals (2024-2029):** Ensure no knowledge is lost when seniors graduate
- **Solution:** Create educational presentations on various FIRST topics
- **Objective:** Provide reference material for future generations to push the limits of the previous season

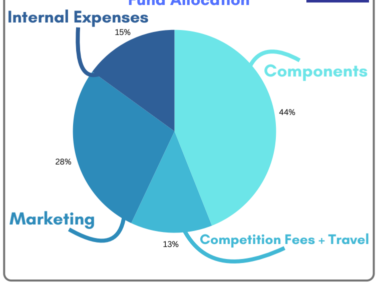
Financial Plan and Expense Report

Financial Plan

We focus on long-term financial sustainability to ensure success. Financial support comes from two different sources: sponsors and contributions. In 2023 we launched our own financial vehicle: Taksh Foundation, a non-profit organization created to support all students passionate about STEM disciplines. The association was founded by parents, mentors, and our team.
The approved budget this season is $4000 taking into consideration the multitude of events we want to invest into. Achieved budget by the beginning of February is $3612 primarily provided by Patel Brothers, Crave Infotech, Spice Paradise, and Top Cricket.

In addition, the following sponsors have provided us with materials and software at a free/reduced cost: Andymark, GoBuilda, Rev Robotics, and Onshape.

Fund Allocation



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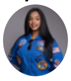
Industry Mentors

Our mentors supported us through tough times with their expertise and guidance.

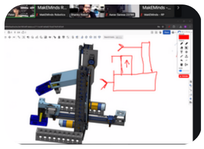
New Mentors

Priya



Guided engineering principles & mechanism optimization in our robots structure.

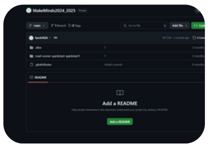
First Alumni
Pursing Aerospace Engineering from Cornell



Mr. Nachiappan

Helped with code structure and debugging different aspects of our autonomous

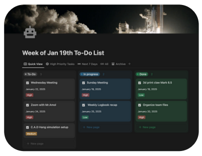
Works at Meta



Mr. Amol

Streamlined project management and workflow, introducing us in utilizing Notion effectively

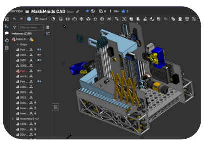
First Alumni
VP IT at Marsh



Ms. Priyal

Helped team organization and outreach by implementing structured communication strategies

MS in Data Analytics



Sustained Mentors

Sankarshan

Supported mechanical problem-solving aspects such as developing ideas for our hang.

Robotics Engineer & STEM Innovator

Mr. Praveen

Taught GitHub practices & structured coding principles allowing for more efficient coding practices.

Board member of Maryland Stem Festival

Nishant

Managed social media presence for outreach by teaching us about the importance of social media consistancy.

Social Media Influencer

Rudra

Enhanced CAD and 3D modeling skills introducing us to Onshape Simulation & Renders

FIRST Alumni
Pursuing Mechanical Engineering from UMBC

What They Taught Us

- Using **PID controllers** for precise movement.
- Proper **code structure** and debugging best practices.
- Best practices for **GitHub** and version control.
- Mechanical **optimization** using **engineering principles.**
- **Branding** and outreach strategies.

How we acquired our mentors-

Reaching out via **Instagram DMs** & **LinkedIn** to **FIRST alumni and engineers**.
- Attending **STEM events** to network with professionals.
- Engaging with **technical experts** for long-term guidance.
- Developing virtual and in-person **connections** in STEM.

Our Design Process

Our Engineering Design Process

Identify
Define
Ideate
Prototype
Test

This **Engineering Design Process** lets us have a proper workflow and also keep an **organized method** to work. It helps us make **efficient and useful** parts for the robot through **logic, creativity, research,** and **trial and error**.

1) Identify: *Identify the objectives / goals of the game.*

When watching the season trailer on a call as a team, we found out that:

- The game revolves around "samples", rectangular prisms scattered across the mat.
    - Specimen were deemed as our main interest as they have a lot of points and can be done fast.
    - In order for us to get the specimen, we needed a way give the samples to the human player fast.
- The objective that we had was having a dependable level 2 ascent and possibly even going to level 3.

2) Define: *Define the constraints of the game and define ways to approach the problem.*

- **High Rung Height:** We found out that the height of the high rung for the specimen was a fixed 26 inches.
- **High Baskets Height:** We found out that the height of the high basket was a fixed 43 inches.
    - In our design, we knew that we not only had to accommodate for the high rung, but also for the high basket.
- **Samples** - the main scoring elements.
    - We knew that we needed a proper way to pick them up as they had grooves in them which would be tough to get a good grip on.
- **Weight Constrains** - Weight plays a huge role as we need it to be light as possible in order for us to hang our robot without it touching the ground.

3) Ideate: *Pinpoint the method you want to use to overcome the problem and brainstorm ideas.*

We used sketches and building small versions of our ideas to envision it and see how it would work on the field. We later came up with some ideas which were:

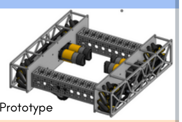
- A **viper slide** system for reaching high places such as high basket and putting on high rung.
- A **claw** mechanism for getting samples and placing them in the baskets
- A **hanging channel** preferably a 2 hole or 1 hole channel.
- Another channel on the side connected to a flat large channel to achieve level 3 ascent.

4) Prototype: *Virtually prototype using CAD and/or create a physical prototype.*

To better envision our ideas, we used **Computer Aided Design (CAD).**

- After deciding on ideas, we made CAD prototypes, iterating on them multiple times before making physical prototypes to see if they would work on our robot and be efficient.

Prototyping is a crucial part of the design process, as it allowed us to recognize any possible flaws in our designs helping us in the long run.


An early CAD Prototype

5) Test: *Test the prototype and look for ways to improve the design's flaws or issues.*

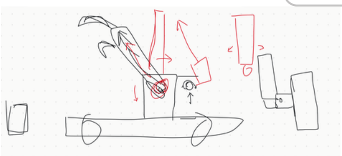
- Not only was this more efficient, but it also allowed our newer members to gain **experience** with the design process.

After, we tested our mechanisms using code. This helps us actually control it for its intended reason and see how it functions.

From this point on, we continue to cycle between testing and building prototypes until we find one. Throughout this process, we have gone thorough many **iterations** which have taught us valueable engineering concepts and allowed us to create our current design.

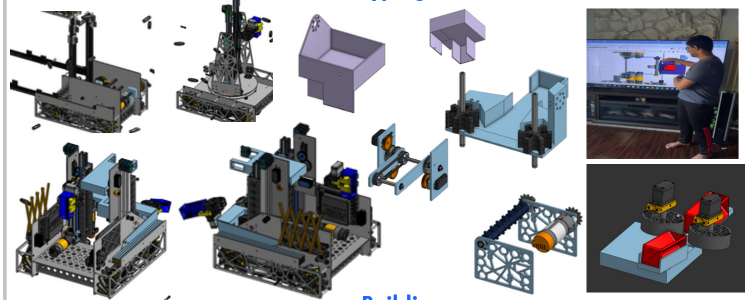
Our Development Process

Brainstorming

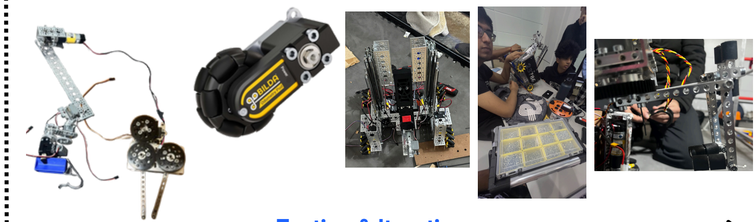


Ideas:
- Claw to pick from sides of sample
- hang that is sturdy and won't move as much
- worm gear with viper slide to hold robot

Prototyping & CAD



Building



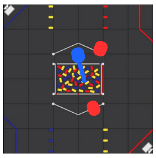
Testing & Iterations

Game Strategy

TeleOp Strategy

Basket Side

During Teleop, we want to score as many points as possible while depriving the other alliance of as many samples as we can. Therefore, we created an **easily adaptable** strategy that plays **defense** against **both** of the opposite alliance robots while we **continuously score points**. We decided to **prioritize** picking up samples from the **middle** of the submersible, decreasing the amount of space the other alliance specimen robot has to pick up samples while decreasing the amount of easily, available yellow samples that the other alliance can use.



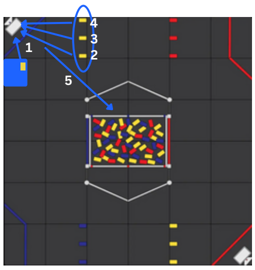
Specimen Side

We wanted to remain free of most defense while still being able to efficiently pickup samples. As a result, we decided to pick up samples from **2 sides** of the submersible, near the chambers and near the opposing alliances ascent zone. We also decided that it was important to **"get in the groove"** during matches and thus decided to collect **multiple** alliance-specific samples **in the first minute** and score them as specimen **in the second minute**.

Autonomous Strategy

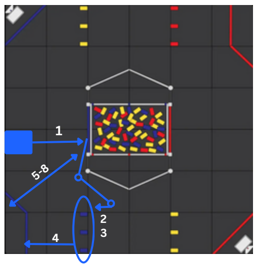
Basket Side

On the side closer to the baskets, our robot aims for **4** samples in the **high basket**, along with a Level 1 Ascent. This brings us to **35 points** in the Autonomous period, and 67 points, when it ends. First, we put a **preloaded sample** into the basket, then we take the **three preset samples** one by one, place them into the basket, and then park.



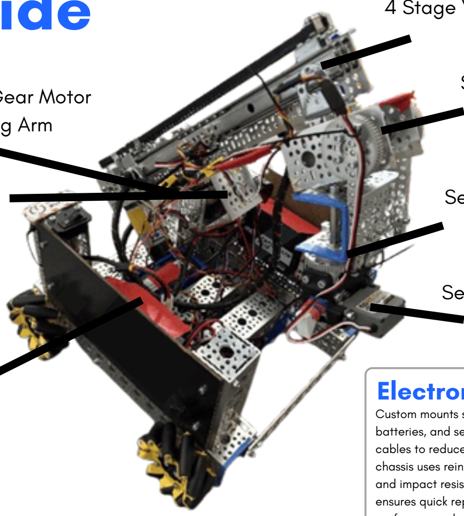
Specimen Side

Our robot starts with a pre-loaded specimen and hangs it on the high chamber. Then it pushes **all three** samples into the net zone for the human player to turn them into specimens, as well as the extra alliance specimen, for the robot to hang onto the high chamber. This gives us a total of **50** points.



Robot Overview

Riptide



Electronics

Custom mounts secure the control hub, batteries, and sensors, with organized cables to reduce clutter. The lightweight chassis uses reinforced bracing for rigidity and impact resistance. Streamlined layout ensures quick repairs and reliable performance during matches.

Arm and Claw Subsystem

The Arm & Claw System is designed for precise manipulation and scoring of game elements. Powered by a high-torque 28:1 worm gear motor, the arm efficiently lifts and positions objects, while the 4-stage Viper Slide provides adjustable reach to accommodate varying scoring heights. Three dedicated servos control the claw's arm, wrist, and grip, enabling nuanced movements for secure pickup and placement. This subsystem's modularity ensures adaptability across different game scenarios, making it a critical component for consistent scoring during both autonomous and driver-controlled periods.

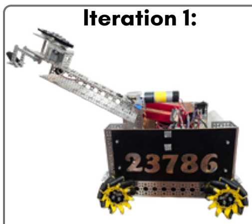
How We Hang

This subsystem maximizes endgame points through speed and reliability. Using a compact hook paired with the 28:1 arm and Viper Slide, the robot ascends swiftly to the hanging bar and locks securely. Designed for rapid deployment, it minimizes downtime in the final moments, transitioning seamlessly from scoring to hanging. Robust construction ensures stability, keeping the robot suspended to secure additional points.

Robot Iterations

Our drivetrain has changed a lot throughout the season. It has many of the same subsystems though they have been modified and changed to fit our needs.

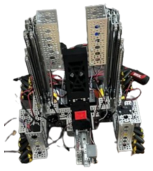
Iteration 1:



- Large, bulky, **ineffective claw**
- the middle had **no wire management**
- Can **only** score specimen on the high chamber and **samples in the lower basket**
- **Cannot** do level 2 ascent
- **Not enough reach** into the submersible zone
- Plow system to push samples on the field
- **not pass through** - must turn around for **every** cycle

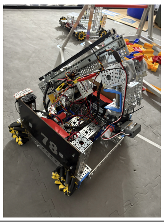
Iteration 2:

- wider chassis to take up **more space on the field**
- **stable** 2 slide lift
- Made for faster sample cycle times - **pass-through** design
- **prevents tipping** due to the absence of slide rotation
- **Weighs** a lot **more** compared to iteration 1 and **requires** a **transfer**
- horizontal slide run by **slow** servos - ends up **slowing down cycle times**
- Odometry pods located outside of the robot for **more accurate localization**
- **slow** linear actuators needed to lift weight - **over 15 seconds** for level 2 ascent



After completing both robots, we did a **side-by-side comparison** and determined the features we **valued** most from each design. The first design was more favorable, as it was fairly **easy to maintain** and **easy to operate**. However, the second design was very bulky and difficult to maintain due to **overcomplexity**. In addition, we accomplished **faster cycle times** with the first robot. As a result, we decided to **combine the best facets of both designs into a third, more competitive design.**

Current Iteration



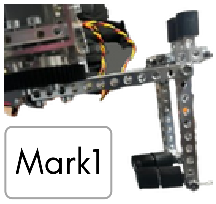
- A **small** and **light-weight** chassis
- capable of **clean wire management**
- has a single rotatable slide for **effective cycling**
- **simple** and **transfer-less** design
- retracts for **high-speed**, **low linear displacement side rotations - prevents tipping**
- can do level 2 ascent in **under 5 seconds**
- easily **maintainable**
- has a single plow system
- 2-axis claw to easily **pick up samples in any orientation**
- **Pass through** design for **faster cycle times**

Claw Iterations

based structure to incorporating 3D-printed componer
efficiency improvements, allowing for more effective
development followed a structured **engineering proc**
Mark 1 through Mark 8 as a nod to Iron Man's evolving s

September

- Constructed using goBILDA parts with **rubber ends for grip.**
- Capable of picking from **only certain angles.**
- Operated with **one servo** for control



Mark1

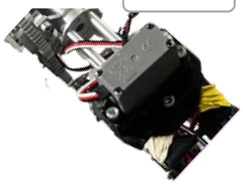
October

- Adjusted design to **better fit grooves.**
- Introduced rubber bands to prevent unwanted movement.
- Added wrist-like motion for **flexible picking angles.**
- Incorporated **three servos**

November

- Competed in our second major event of the season, **stress-testing** the claw in a real match environment.
- **Discovered weaknesses** in our design under match conditions and **made adjustments**

Mark5



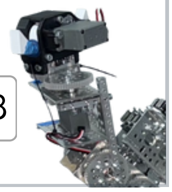
December

- **Faced challenges** with frequent claw breakdowns, prompting design improvements.
- **Implemented an indirect power method** to protect the servos from damage.

January

- Refined the claw to be **reliable**
- Focused on **consistency** and **efficiency** in picking up elements under **time constraints.**
- Optimized Driver controls for **easier use**

Mark8



Programming

Components / Sensors

- **3 High Precision Odometry Pods** – goBILDA wheel encoders for localization.
- **Inertial Measurement Unit (IMU)** – Backup sensor for heading correction.
- **Encoders on all the Motors** – Ensures precision in all of our robot's motors.

Season Evolution

1. At the beginning of the season, we used encoders, but there was a lot of wheel slippage and unnecessary drift, which would hinder the success of our autonomous and other robot endeavors.

2. Because of this issue, we decided to use two odometry pods along with our IMU and Roadrunner, which was about 24% more accurate, but Roadrunner could not respond to drift still and the IMU would veer off sometimes.

3. This caused us to use PedroPathing, that has ultra accurate paths along with 3 odometry pods to make sure that the IMU would not drift. This increases our success rate by around 15%.

54% +24% **78%** +15% **93%**

autonmous success rate

Gamepad in TeleOp

Drivetrain: Our team uses a field-centric drive system, which means that the robot's movement is controlled relative to the field rather than its orientation. This allows the driver to move the robot intuitively—pushing forward on the joystick always moves the robot forward on the field, regardless of which way the robot is facing.

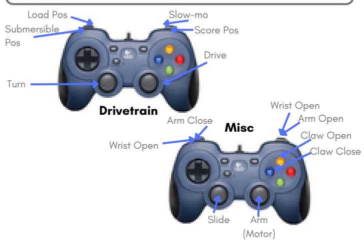
The robot has a slow mode that can be activated with a button press.

Additionally, on this gamepad are preset positions for our claw, wrist, and arm servos: a scoring position, a load position, and a submersible pickup position.

Misc Gamepad: This gamepad has a wide variety of controls, such as slide controls, arm controls, and manual controls for all the servos, and is mainly utilized to control the arm and slide on the robot while allowing for micro-adjustments to be made to the servos. The claw and wrist servos are often controlled by this gamepad.

More on Pedro Pathing

Since the odometry pods on our robot provide continuous positional feedback, Pedro Pathing can adjust wheel velocities and paths in real-time. During autonomous, if the robot deviates due to a collision, the path is recalculated to the target using updated odometry data.



Mathematics

3-Wheel Odometry Kinematics

The way that the coordinate frame works in Pedro Pathing is that the origin is the robot's center, and the Pod's positions are the following:

- Pod 1: Positioned at (a,0) (right wheel, parallel to robot's forward direction).
- Pod 2: Positioned at (-a,0) (left wheel, parallel).
- Pod 3: Positioned at (0,b) (orthogonal to forward direction).

Forward Kinematics:
Each pod's displacement ($\Delta s1$, $\Delta s2$, $\Delta s3$), is related to the robot's motion (Δx, Δy, $\Delta\theta$):
$\Delta s1 = \Delta x - a\Delta\theta$
$\Delta s2 = \Delta x + a\Delta\theta$
$\Delta s3 = \Delta y + b\Delta\theta$

Inverse Kinematics
Now, solving for (Δx, Δy, $\Delta\theta$), using inverse matrices, we get:

$$\begin{bmatrix} \Delta x \\ \Delta y \\ \Delta\theta \end{bmatrix} = \frac{1}{2a} \begin{bmatrix} a & a & 0 \\ 0 & 0 & 2a \\ -1 & 1 & 0 \end{bmatrix} \begin{bmatrix} \Delta s_1 \\ \Delta s_2 \\ \Delta s_3 \end{bmatrix} \longrightarrow \begin{aligned} \Delta x &= \frac{1}{2a}(a\Delta s_1 + a\Delta s_2 + 0 \cdot \Delta s_3) \\ \Delta y &= \frac{1}{2a}(0 \cdot \Delta s_1 + 0 \cdot \Delta s_2 + 2a\Delta s_3) \\ \Delta\theta &= \frac{1}{2a}(-1 \cdot \Delta s_1 + 1 \cdot \Delta s_2 + 0 \cdot \Delta s_3) \end{aligned}$$

This effectively shows a clear translation for each of our variables and completes the localization.

Bezier Curves

A Bezier curve of degree *n* is mathematically defined by a set of control points P0, P1, ... P of *n*, and the *Bernstein* polynomials:

$$B(t) = \sum_{i=0}^{n} \binom{n}{i} (1-t)^{n-i} t^i P_i, \quad t \in [0,1]$$

Bézier curves are ideal for Pedro pathing because they stay within the convex hull of their control points, enhancing collision avoidance and predictability. The de Casteljau algorithm allows for efficient real-time adjustments, while B-splines need more control points and complex continuity handling. Overall, their simplicity and robust performance make Bézier curves the superior choice for real-time path planning.

P(I)D Controllers

Proportional, Integral, Derivative

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{d}{dt} e(t)$$

For our FTC robot, we use a PID controller on both the arm and slide, without the Integral term. The Proportional term adjusts the motor power based on the error, while the Derivative term smooths out movement by predicting future errors. For the arm, this ensures precise positioning with minimal oscillation, and for the slide, it helps prevent overshooting and ensures that it accurately stops at the target position. This setup offers smooth and efficient control with less complexity.

Lessons Learned

Our frequent roadblocks were always taken as opportunities for growth - their subsequent solutions always helped us grow as a team. Here are some of the major challenges we faced:

Challenges	Solutions
• Claw had rotation limitations • Drivers struggled to get it in the perfect position to pick up samples and specimens during practice and games	• Developed a new claw that rotated on multiple-axis • New claw has a solid grip on samples and specimens due to special 3d printed grippers and rubber bands
• There were wiring restrictions in our linear slide • Wire would get caught in mechanisms when the claw was rotating and the linear slide was extending	• Used zip ties and special cable connectors throughout the linear slide and around the servos to make sure we could use the full range of motion without the wires getting caught in gears
• When using 2-wheel odometry, our control hub would return noisy values(inaccurate, rapidly changing values) due to an error with the IMU heading returns not being accurate enough, but having the precision the claim that accuracy. • This gave us an error when we used the processed heading it returned to us	• Switched to 3-wheel odometry • Enabled us to calculate the heading from wheel positions • Dealt with the control hub problem
• A specimen once fell into our robot where our wiring was located during a match after a faulty auto • We were unable to do anything for the rest of the match	• Added an acrylic sheet on top of the robot • Covers the wiring and control hub + expansion hub • At an angle for specimens to slide down in case a specimen falls in

Have fun, raise STEM awareness, and build a robot to do impossible things!
MakEMinds 23786