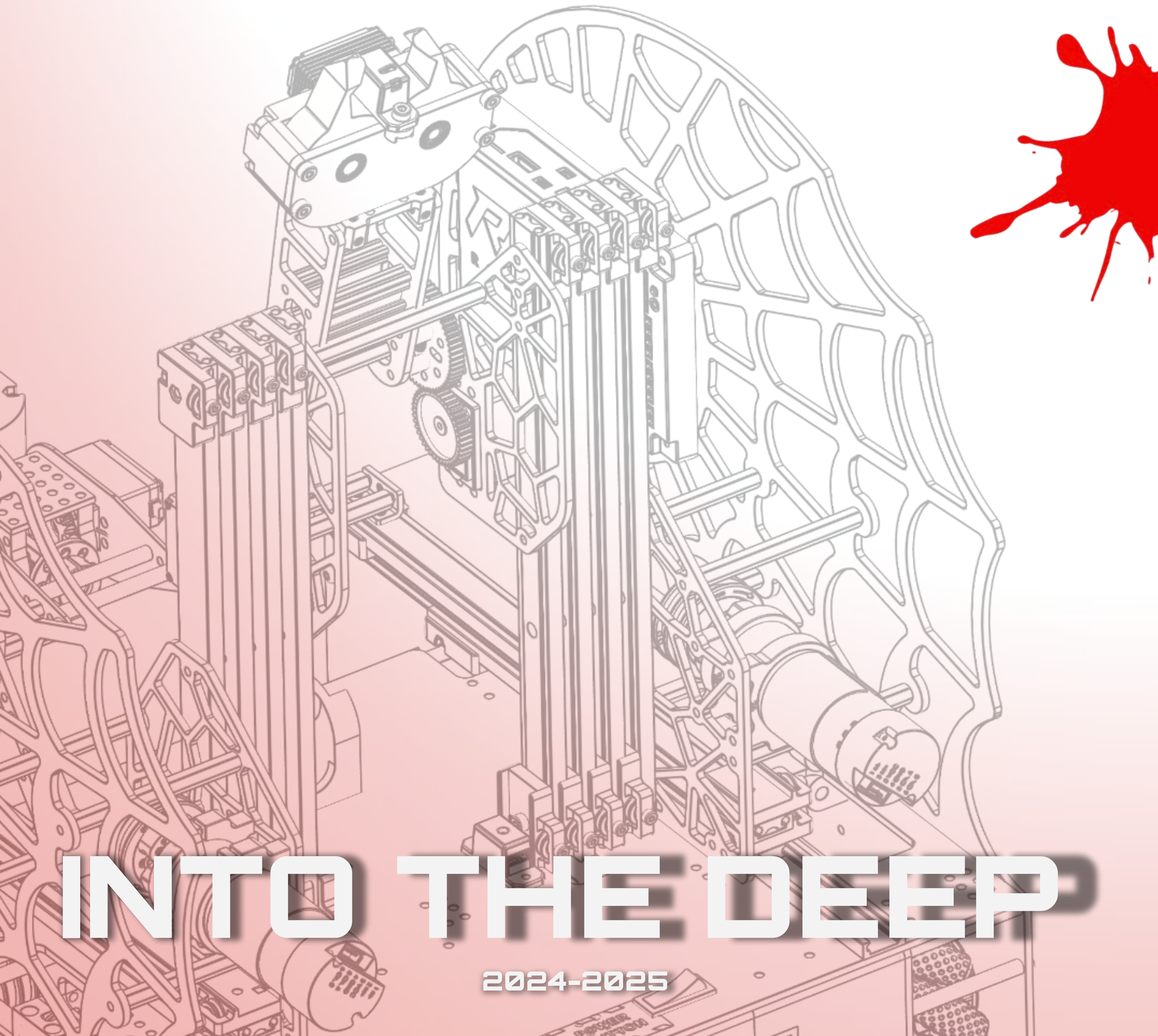
TEAM X #23512 PRESENTS

CARNAGE

ENGINEERING PORTFOLIO



INTO THE DEEP

2024-2025

Portfolio Outline

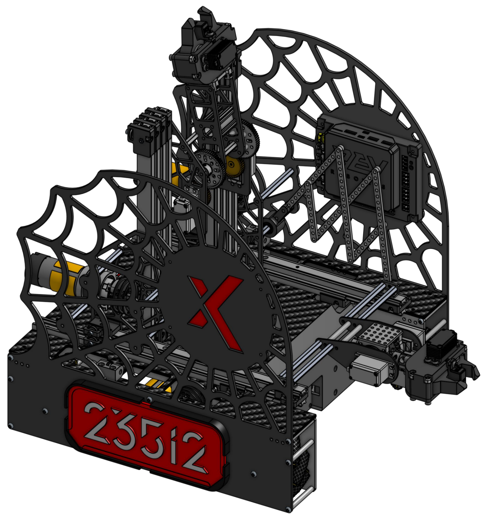
A TABLE OF CONTENTS COVERED IN THIS PORTFOLIO

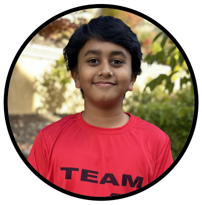
Meet The Team

DRIVING SUCCESS THROUGH TEAMWORK AND LEADERSHIP

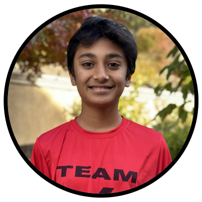
Team Introduction

We are **TEAM X**, a community team based out of Dublin, CA. We have been a team since 2018: five years in FLL, second year of FTC. We are committed to building robots and promoting STEM in **technical and underserved communities.**





RONAV GUPTA
Captain & Design



ARNAV JAIN
Hardware

SAMAR BHOWMICK
Outreach

YAJAT SUNKARA
Documentation

ARJUN MAHAJAN
Software

RAJEEV GUPTA
Lead Coach 1

NEERAJ JUNEJA
Lead Coach 2

Design Strategy

THE BLUEPRINT BEHIND OUR ROBOT

Our design strategy emphasizes innovation, collaboration, and iterative improvement. By focusing on the **robustness**, **adaptability**, and **precision** of our robot, we tackle all challenges efficiently while aligning with **competition goals** and **FTC Core Values.**

Conceptualization
We analyze the game's key tasks, brainstorm ideas, and create CAD models.

Prototyping
We build prototypes to test ideas, uncover challenges, and refine designs through experimentation.

Iterations
We improve designs based on prototype feedback, assuring our ABC's of design.

Final Design
We assemble the robot, rigorously test it, and ensure it's competition-ready.

Accessibility

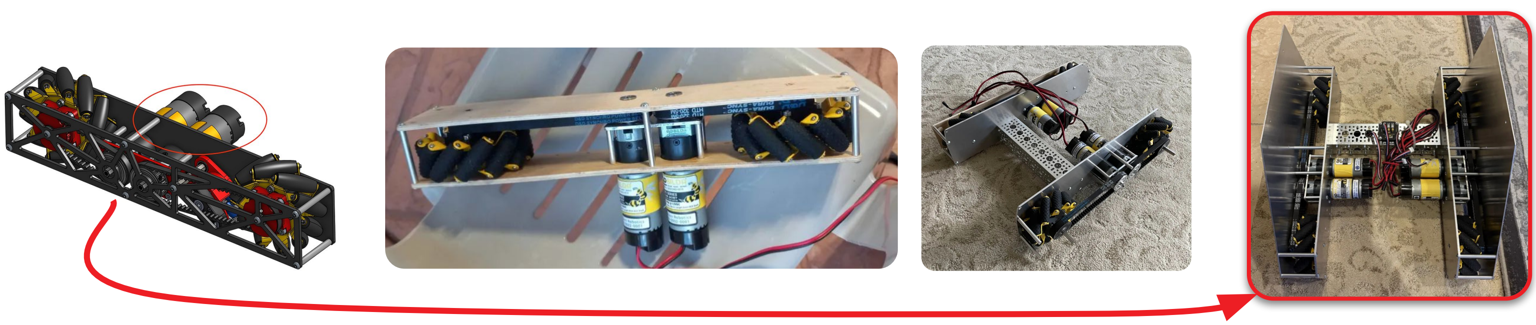
We design while keeping the intention of having easy access to our robot in mind.

Balance

On our robot, we design with a balance between form and function, assuring the best of both worlds.

Compatibility

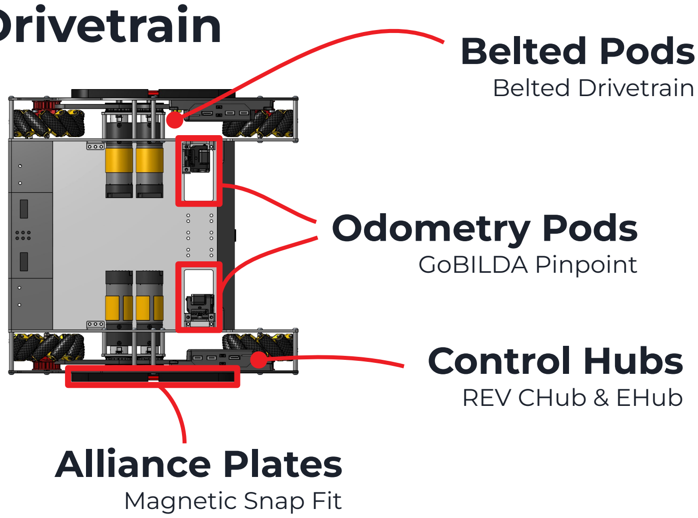
Compatibility allows us to have integration and adaptability through modularity, allowing easy upgrades and replacements.



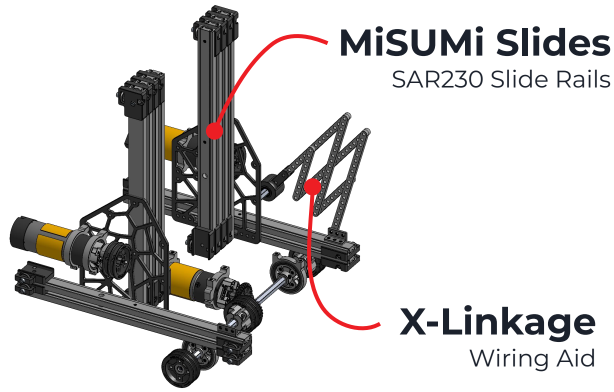
Robot Overview

CREATING INNOVATION FROM THE GROUND UP

Drivetrain

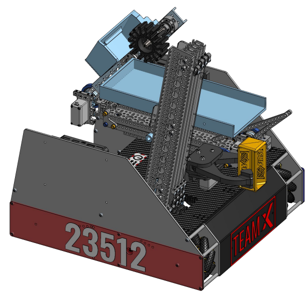


Extension Systems



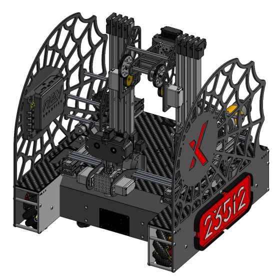
In-House Machining

We use our own CNC machine to cut different materials, such as **6061 aluminum** and **polycarb**. This led us to learn CAM and other vital workshop skills.



Q1 Robot - *No Name*

The gameplay is decent, with solid strategy and execution, but the cycle times are slow, which impacts overall efficiency.



Q2 Robot - *CARNAGE*

The improved design has cleaner mechanisms and faster cycle times, enhancing efficiency, reliability, and competitiveness during matches.

Belted Drivetrain

Our drivetrain is belted, meaning the motors are essentially packaged in the center of our robot. This **helps with balance** and prevents toppling. The belts also make driving **smoother than usual**.

Intake

Our intake is a servo-powered claw, mounted on a **differential gearbox** wrist. This allows for many degrees of freedom, enabling a **fast** and **reliable** intake.

Deposit

The deposit is the **same claw as our intake**. It is connected to a custom outtake arm that mounts to our vertical slides. This mechanism deposits **both samples and specimen** with ease.

Belted Drivetrain

DRIVING THE FUTURE OF MOBILITY

Design Requirements

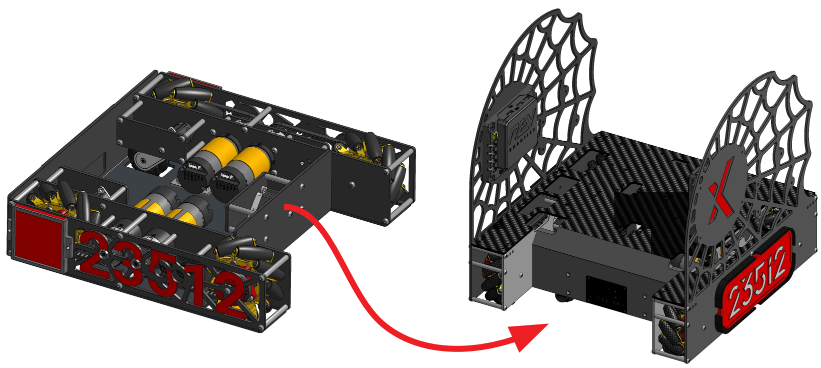
- Space for accessibility and wiring
- Low CG for balance
- High speed, fast motors (435 rpm)
- Smaller than our old GoBILDA Strafer Chassis drivetrain (~15”x16”)
- Structurally integral (⅛” 6061 alu)
- Pocketing for weight and aesthetics

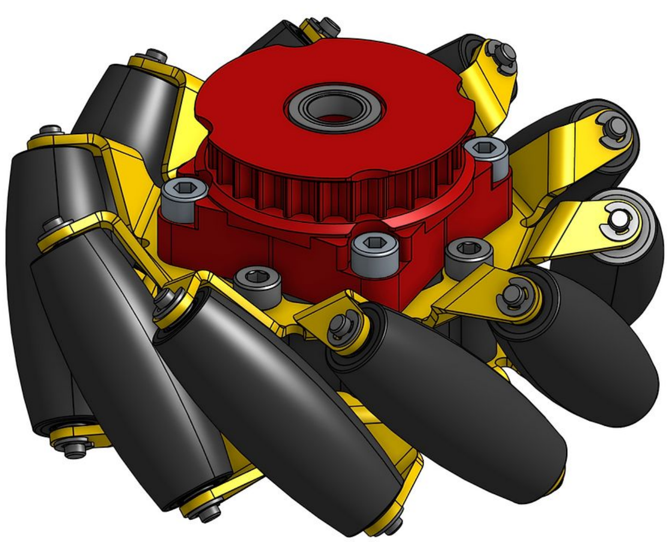
Learning From Mistakes

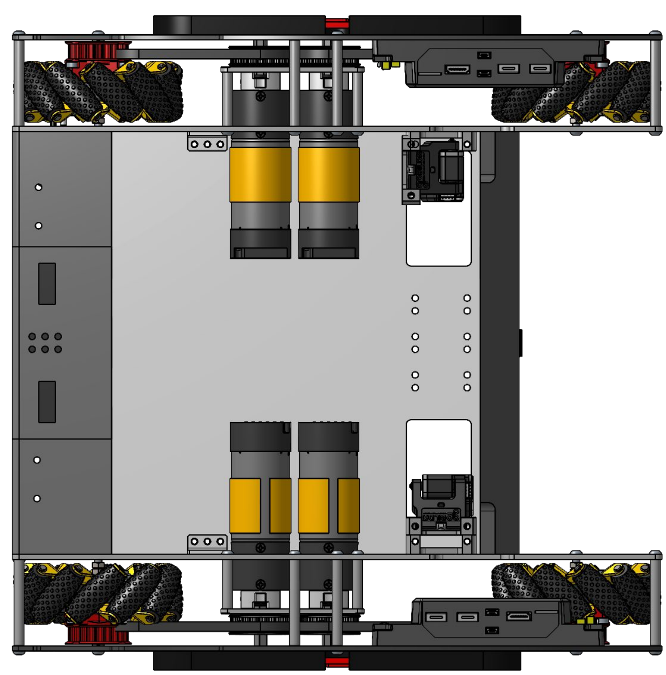
Last season, we used the GoBILDA Strafer Chassis for our drivetrain, which performed great. However, our robot had **severe balance issues** and would tip a lot. This led us to switch to a **custom belted drivetrain**, which is designed with the weight of the motors in the middle of the robot, balancing it out.

Iterations

Pros:
- Better accessibility and wiring
- More accurate odometry
- Updated alliance marker rules
- Cleaner mounting for battery
- Added AI vision (Limelight 3A)





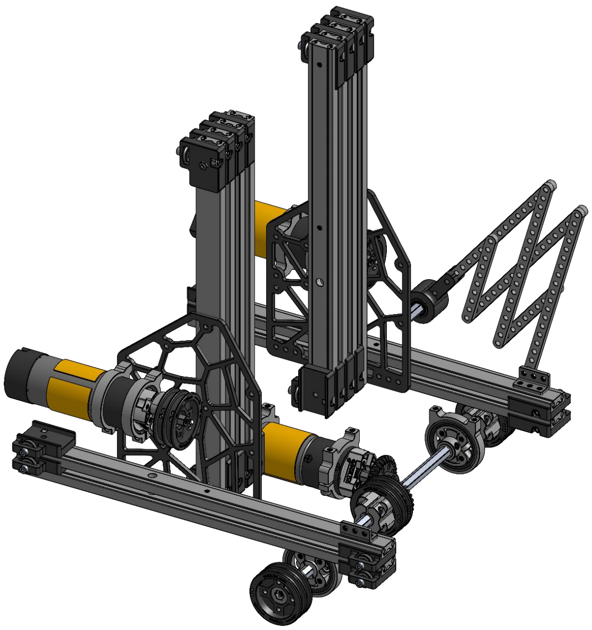


Extension Systems

EXTENDING THE DIMENSIONS OF POSSIBILITIES

Design Requirements

- Horizontal extension must stay within the 20” x 42” limit
- Must remain sturdy at full extension
- Needs the height to reach the 43” high basket and the length for consistent submersible intake from any side



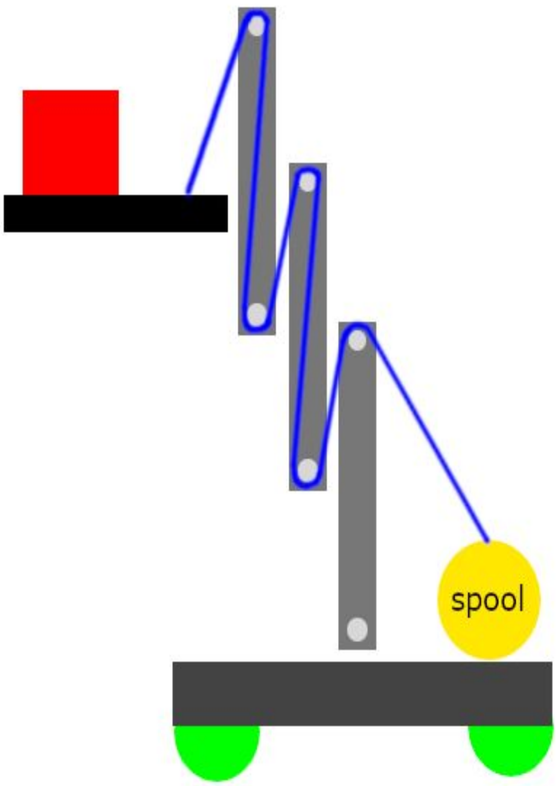
Continuous Stringing

By stacking multiple **MiSUMi SAR230 slide rails** and connecting them with **custom 3D prints,** we can create linear slides. To control these slides, we use **2 continuous strings** winched on a double spool. One string is used for extension and one is used for retraction. Our retraction strings have springs to maintain their tension at all times. We also have **custom V-groove pulley mounts** around our robot, helping our retraction string navigate free of any possible obstacles.

Improvement

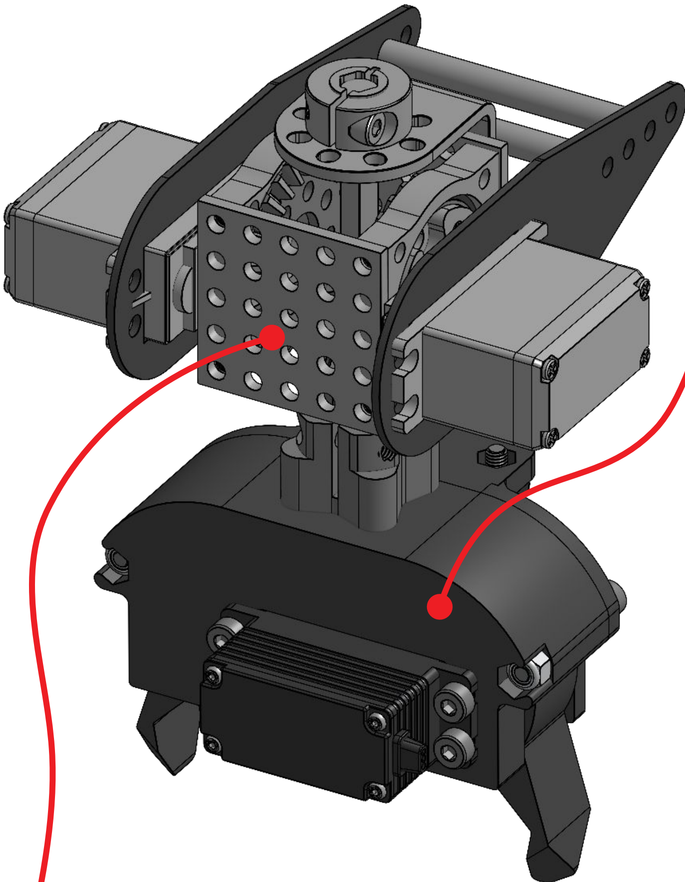
This is our first time rigging linear slides with string, and we’ve learnt a lot from the experience. Potential improvements that we can and will implement are:

- Custom spools with V-shaped walls that prevent string from entangling
- Different color string for extension and retraction
- Tensioning springs with strengths corresponding to the torque of the motor
- Faster motors
- Cascading stringing



Intake & Transfer

BEHIND THE NUTS AND BOLTS OF OUR INTAKE



Intake Claw

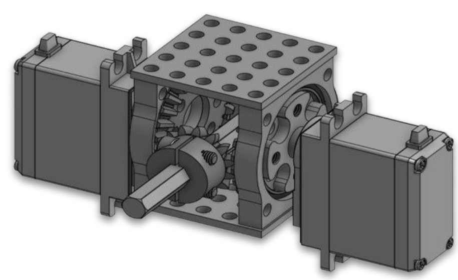
Our intake claw is servo powered, using herringbone gears to rotate both fingers at the same time.

Linear Slide Integration:
Our claw is mounted on our horizontal slides, allowing us to reach into the submersible to pick up **any sample we want.**

Color Sensor Integration:
With our built-in color sensor, we can **avoid intaking opponents' samples** and create a state machine to **speed up TeleOp cycles**. For instance, if it detects a yellow sample, our robot will automatically go to the high basket without the driver having to think.

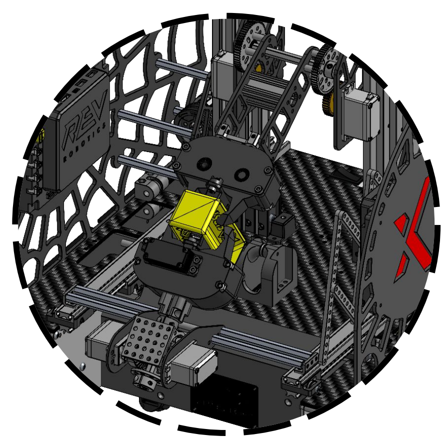
Differential Gearbox

We use a differential gearbox, which gives us two more degrees of freedom. This allows our robot to execute different maneuvers with ease and accuracy, speeding up our Autonomous and TeleOp gameplay.



Transfer to the Deposit

Our robot uses two claws: one for intake and one for outtake. To transfer game elements between them, the intake claw uses the diffy mechanism to rotate to the perfect angle for the outtake claw to grab the element. This design makes the transfer fast and reliable, helping us score efficiently during matches.



Simple Deposit

EFFICIENT SCORING AND DURABLE DESIGN FOR MAXIMUM IMPACT

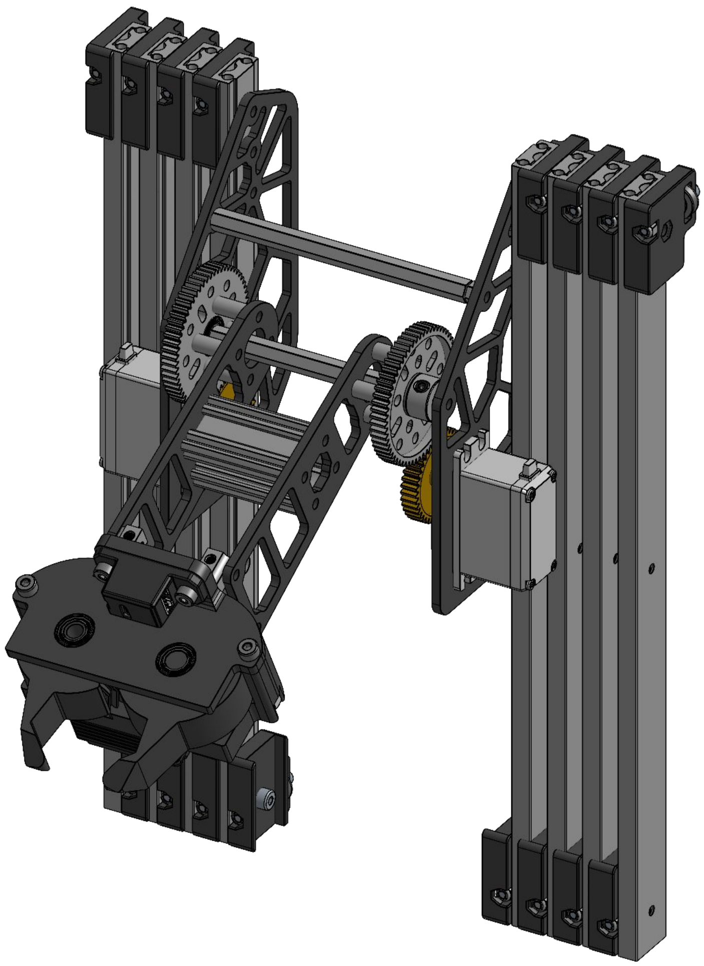
Outtake Arm

For our deposit, we developed an efficient dual-servo pivoting outtake arm that scores and transfers game elements.

Robust and Modular Design:
This mechanism relies on a durable aluminum frame and pocketing, adding stability, while remaining lightweight.

Last season, we broke many servos in our claw by direct driving them. We applied this learning to our design for this season, which now uses a simple gear train and allows for a more robust design.

Quick Extension with Linear Slides:
MiSUMi linear slides enable precise extension, reaching both the high basket and high chamber with high speeds.



Why Linear Slides? Why MiSUMi?

We wanted to score **the most points possible**, meaning high basket and high chamber, which isn't possible without linear extension. To achieve this extension, we use MiSUMi slide rails. Due to their lightweight aluminum properties, they are **much faster than older iterations**, which used slow GoBILDA Viper-Slides made of steel.

K.I.S.S. Design Principle (Keep It Simple, Stupid)

When designing this mechanism, we kept K.I.S.S. in mind, a very important design principle. We wanted something that was very simple, but effective. By using this outtake arm combined with our vertical linear slides, we can reach all the necessary positions with ease: transfer, basket, and chamber. This makes our deposit very straightforward for our programmers to code and for our drivers to use.

Software Strategy

TURNING IDEAS INTO PRECISION ENGINEERING

Our software strategy is designed to create a seamless integration between the robot's hardware and its operational capabilities. We focus on two main areas: **Autonomous** and **TeleOp**, supported by **engineering best practices**.

AUTONOMOUS STRATEGY

For Autonomous, we need to make sure the robot always knows its **exact location** on the field. To achieve this, we utilize GoBILDA Pinpoint odometry, which provides precise tracking of the robot's movement.

To translate this position data into reliable movement, we implement **PID control.** PID dynamically corrects the robot's path in real-time, ensuring precise navigation and alignment with field elements.

TELEOP STRATEGY

For TeleOp, we take a **customer-centric approach**, where our drivers—our 'customers'—define the controls that work best for them.

Through collaborative feedback, we design software with intuitive keybindings, sensitivity adjustments, and driver-assist features like automated scoring mechanisms. This approach **enhances the drivers' instincts and efficiency** during matches.

ENGINEERING BEST PRACTICES

To ensure reliability and scalability, we adhere to following engineering best practices:

- **Test Driven Development:** Using the **Pedro Pathing** virtual simulation tool, we design and test our autonomous paths before running them on the robot. This allows us to identify and resolve potential issues early, saving time and ensuring a more reliable Autonomous mode.
- **Version Control:** Using Git to track changes and maintain code integrity.
- **Peer Code Reviews:** Ensuring quality and consistency through feedback.
- **Clear Documentation:** Keeping detailed records of code functionality and system design for future reference and easy collaboration.

These practices ensure our software remains robust, maintainable, and ready for continuous improvement.

Limelight & Sensors

THE EYES OF OUR ROBOT

We use data from our AI vision camera, sensors, and encoders to make a consistent robot with **minimal errors in gameplay**.

What is Limelight?

The Limelight 3A is a vision system with onboard processing, real-time tracking, customizable detection pipelines, and an easy-to-use web interface.

How we use Limelight:

Autonomous Period: We use vision alignment in autonomous, allowing the robot to confidently intake without a driver.
Driver Assist: During TeleOp, our Limelight helps assist the driver in intake, speeding up our cycle times.

Sensors

- REV Color Sensor V3
    - Used on our claws
    - Detects color and distance
    - **Helps with state machines**

4-Bar Odometry and Encoders

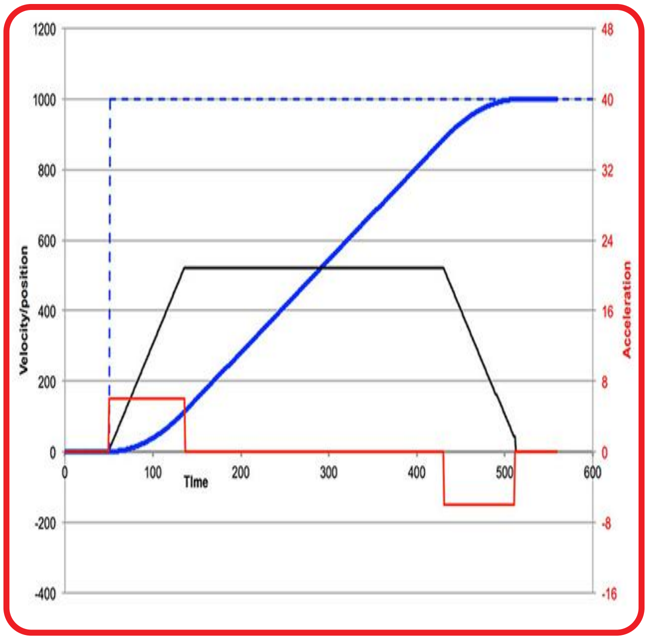
We use a 4-bar odometry configuration with two parallel wheels and an **external IMU** (Inertial Measurement Unit) from the GoBILDA pinpoint computer to track our robot's position and heading accurately.

Localization & Pathing

THE KEY TO EFFICIENT AND ACCURATE MOVEMENT

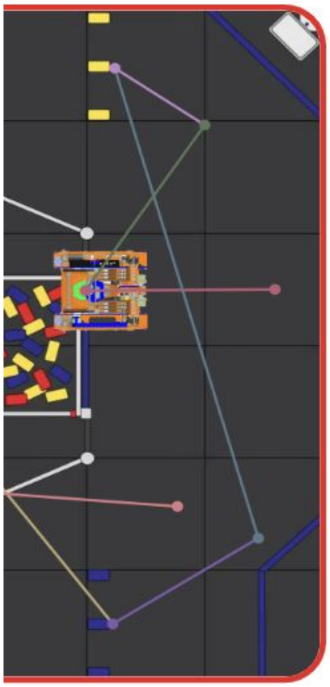
RoadRunner 1.0

At our first qualifier, we used RoadRunner, an open-source library for spline-following. While its motion profiling enhances accuracy, **it slows the robot down** during certain movements to **prioritize consistency over speed**.



MeepMeep

MeepMeep is a **visualization tool** for specifically generating RoadRunner paths in an offline environment. We used it to code our autonomous via test driven development.



Pedro Pathing

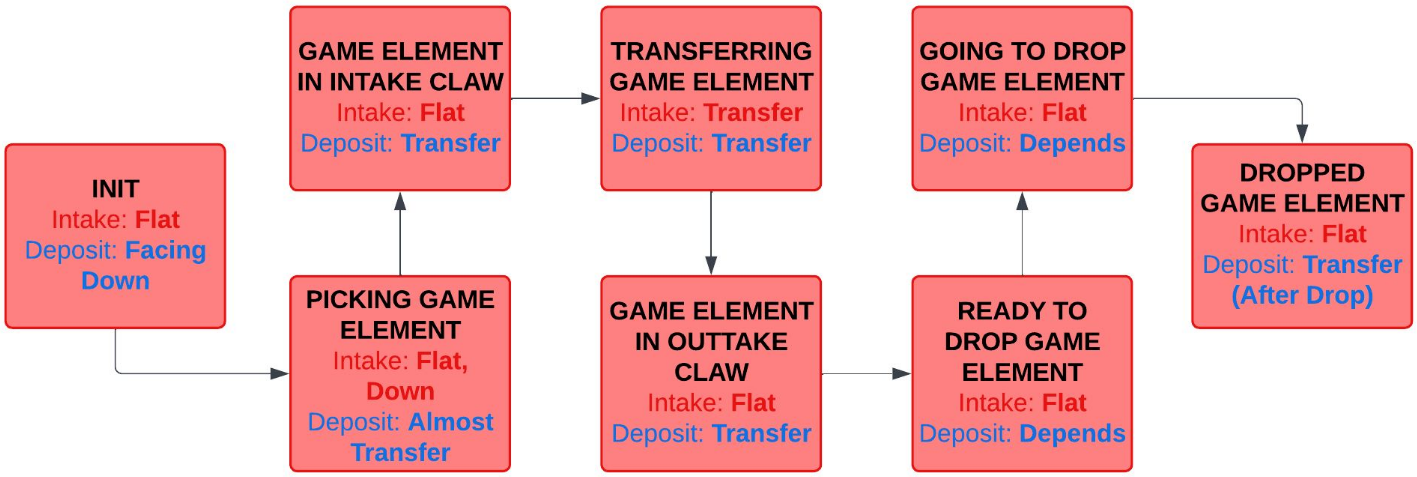
We use Pedro Pathing for precise robot navigation, which ensures our robot consistently follows the intended route. It also always maintains power in the motors, making it **much faster than RoadRunner**. The visualization tool we use for Pedro Pathing is called **Pedro Path Generator**. It has the same features as MeepMeep, but helps generate the path's code for us.

State Machine & PID

DRIVING CONTROL WITH INTELLIGENCE AND ACCURACY

State Machine

We decided to use a **Finite State Machine** for designing and implementing complex logic and achieve clear, maintainable, and predictable robot behavior. Our state machine is **very simple** because it **uses the same sequence for both samples and specimen**, differentiating them via our color sensor input. Ultimately, state machines make it easier to develop and maintain a **high-quality working robot**.



PID and Feedforward Tuning

Tuning the feedforward controller is critical for accurate path following, involving the optimization of kV, kA, and kStatic values to align actual and target velocities. This is achieved through a ramp test, where velocity and voltage data are recorded to refine the parameters for precise movement.

Additionally, the heading and translational (x/y) PID controllers are tuned to ensure accurate trajectories. By adjusting proportional, integral, and derivative gains, the system achieves a balance of responsiveness, stability, and accuracy while minimizing overshoot and oscillations.

Technical Outreach

Online Blogs, Mentoring, Articles, Newsletters, Camps

Mentoring and Assisting

7 teams

We mentor several FTC and FLL teams throughout the world, including the FLL **Team Terrace Tech Titans** (#65169) in **California**, and FTC teams like **Glitch** (#23836), **Rapid Fire** (#25442), **Mastermindz** (#18466)), **Solar Flare** (#25707), **Black Frogs** (#6134), and **Smart Cluster** (#19071) in **California, New York, Michigan, and Romania**. We guide these teams in design, programming, and strategy while promoting the core values of FIRST.

Educational Blog Posts

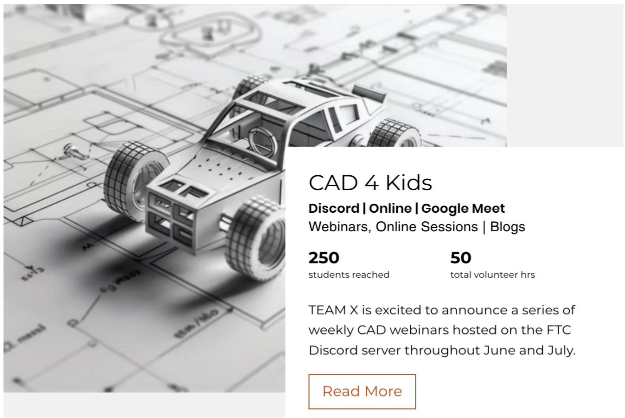
We specialize in delivering exceptional designs for robotics, websites, and portfolios. Through **85+ blog posts,** we share insights into our design process, offering guidance on graphic design, web development, and robot design to help others develop new skills to help them throughout their journey. Over **43,000 people** have viewed our posts!

Python 4 Kids

One of our online outreach events was a Python camp for kids, where we introduced programming through engaging lessons and hands-on projects. The camp built coding skills, confidence, and emphasized teamwork and problem-solving, inspiring the next generation of innovators.

CAD 4 Kids

Another online outreach event we hosted was a CAD for kids camp, where we introduced young learners to the basics of computer-aided design. Through interactive lessons and fun projects, the camp helped kids develop their design skills and creativity.



Non-Technical Outreach

MAKING STEM ACCESSIBLE THROUGHOUT THE WORLD

In-Person Events

8 events

TEAM X engages communities through non-technical outreach, making STEM accessible and fun. Events like the John Green Science Party, Tri-Valley Innovation Fair, Maker Faire, and many more feature interactive exhibits, 3D printing, and DIY robotics. These initiatives spark curiosity and showcase the transformative power of science and technology. We will always continue to do the best in displaying our passion for robotics.

Robot Demonstrations & Scrimmages

We bring our robots to **all of our events**! We even set up our field and showcase the abilities of our robot that peak the interests of many. We love teaching the kids the basics of driving the robot. We also scrim with other teams at these events that gather many.

Spreading FIRST

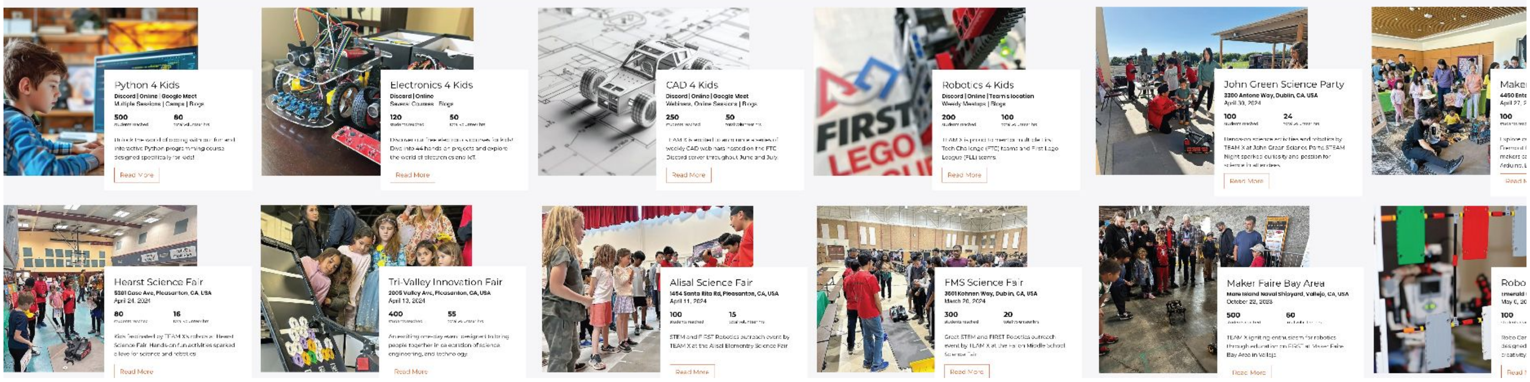
At these events, we love educating parents about the benefits of FIRST robotics and **helping many children get set up with FIRST**. We often also receive many requests from people wanting to start a team or join an existing one **with the help of IGNITE**. Ultimately, we try our best to spread FIRST and have already helped **create 2 teams**.

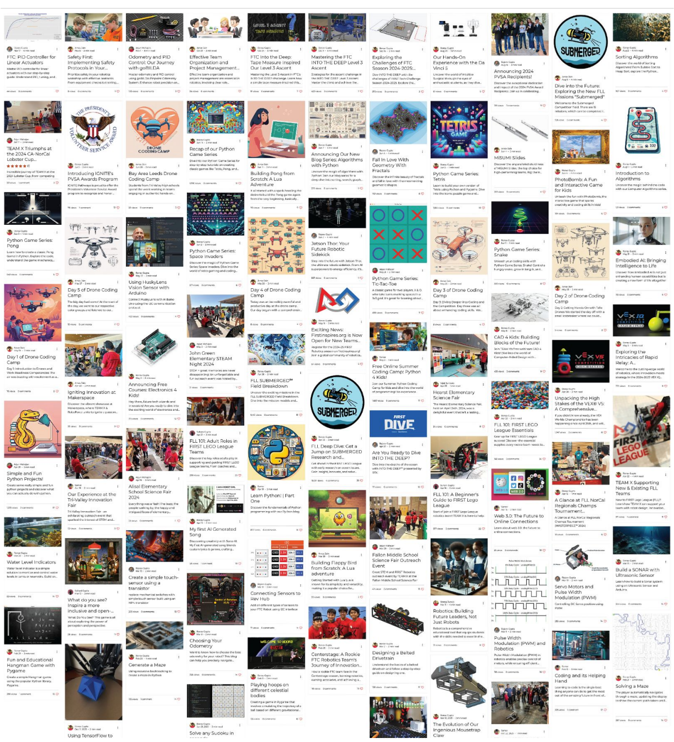
Impact and Growth

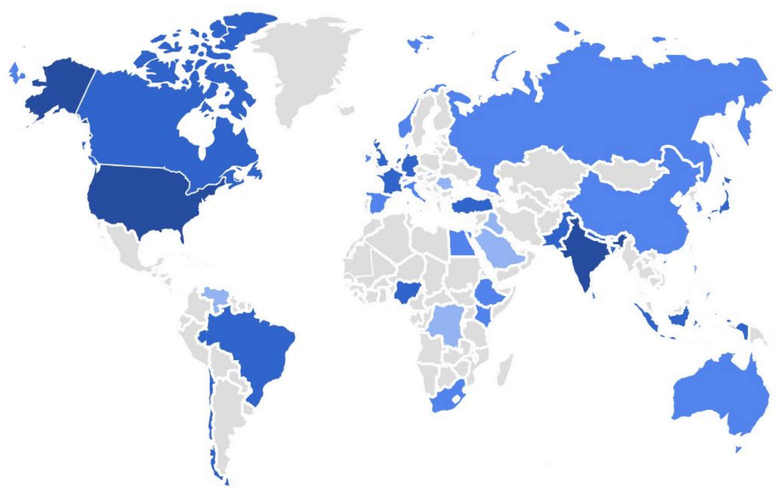
This season, our outreach efforts reached over **3000 people** through workshops, mentoring, and community events, significantly expanding our impact compared to previous years. By inspiring students to explore STEM and supporting new teams, we've fostered long-term growth in the robotics community.

Global Impact

Impact by The Numbers







Reached users in 43 Countries

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