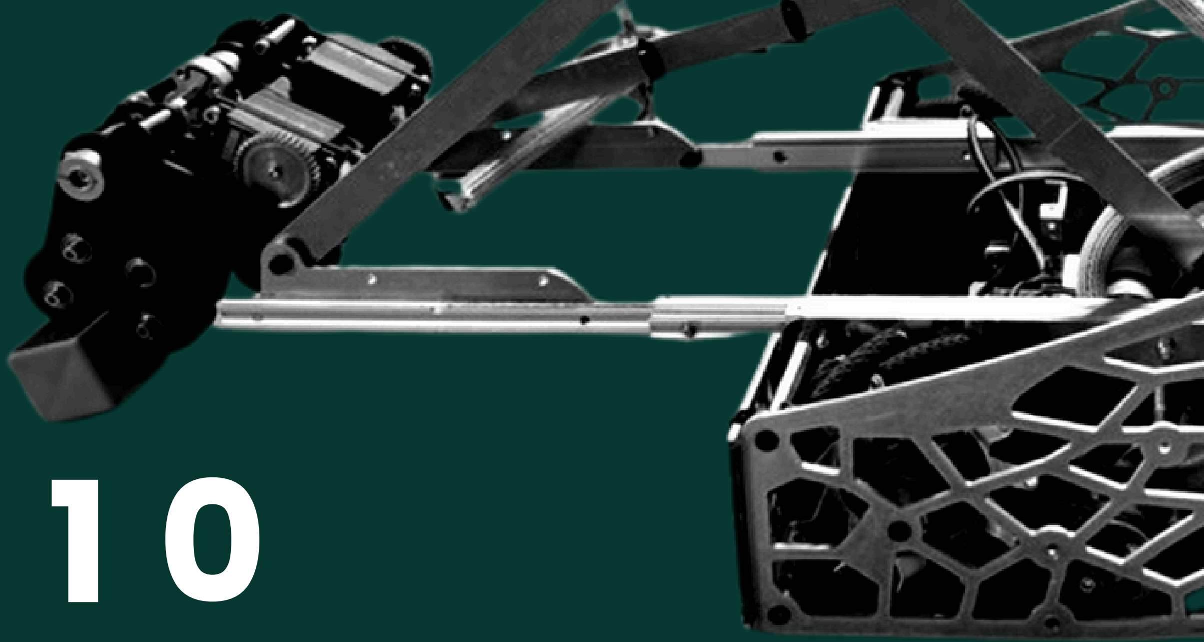

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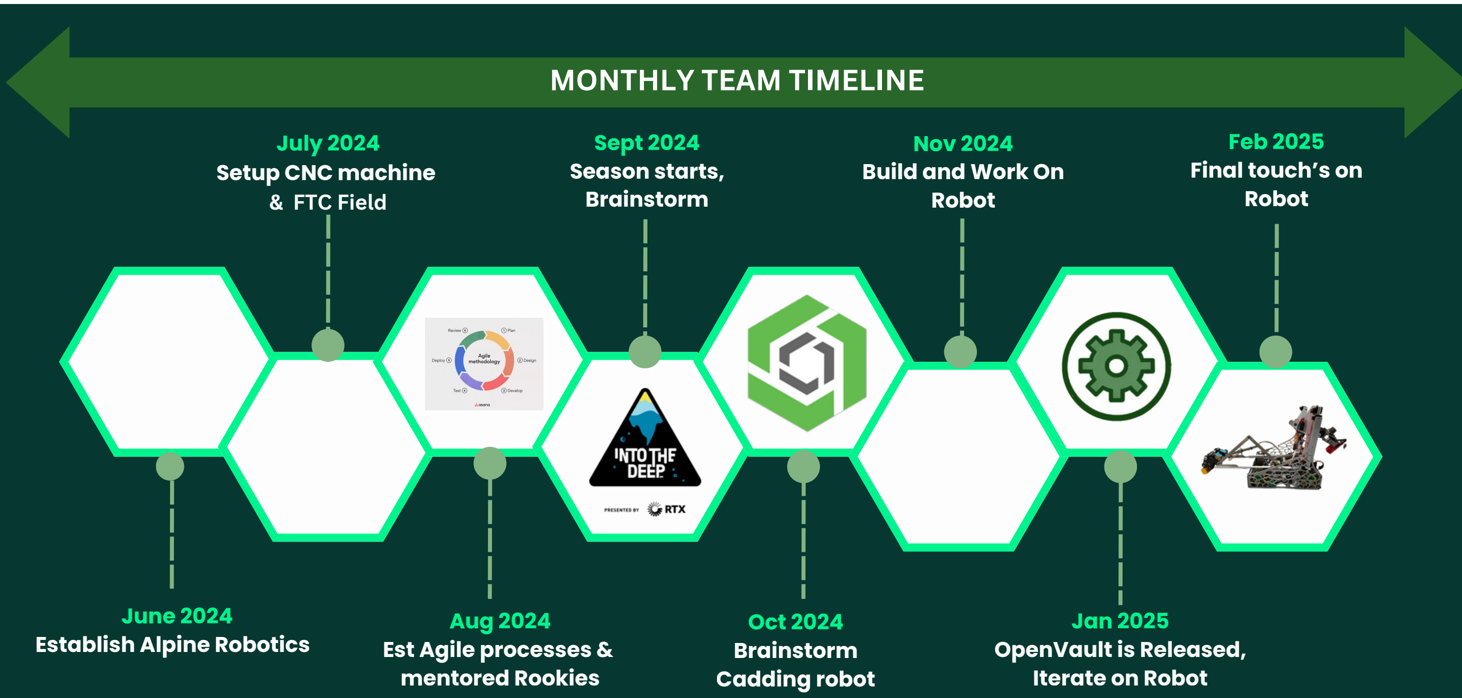
ALPINE ROBOTICS

ENGINEERING PORTFOLIO

2024-2025

Strategic Growth & Sustainability



ROOKIE ACHIEVEMENTS & DEVELOPMENT PLAN

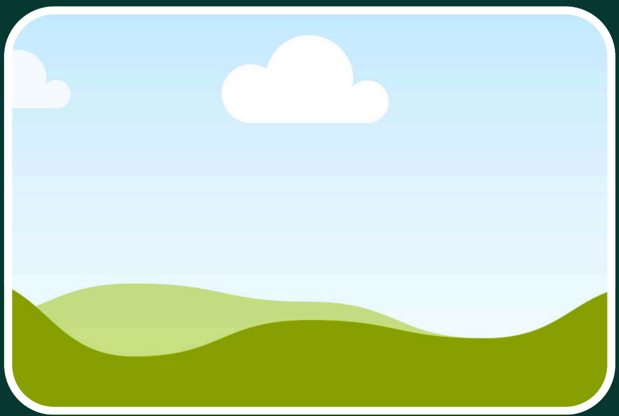
- **HANDS-ON EXPERIENCE & TRAINING** - Rookies helped build drivetrains, wrote basic auton code, and tested mechanisms.
- **WORKSHOPS & DEMOS:** Senior members taught gear assembly, sensor coding, wiring basics to junior team members through multiple working group sessions
- **SHADOWING & OBSERVATION**- Rookies watched mentors wire circuits, code commands, and assemble parts.
- **TEAM COLLABORATION**- worked together on scrum meetings, strategy, troubleshooting robots, and designing mechanisms.
- **CONTINUOUS DEVELOPMENT & LEARNING:** Provide resource to juniors to learn OnShape, Fusion 360, Java and C++ programming.
- **TEAM SUSTAINABILITY LEADS**: Appointed Subleads to establish Team Sustainability.
- **MENTORSHIP & GUIDANCE**- Senior team members taught rookies to make slides, learn CAD, and troubleshoot code.

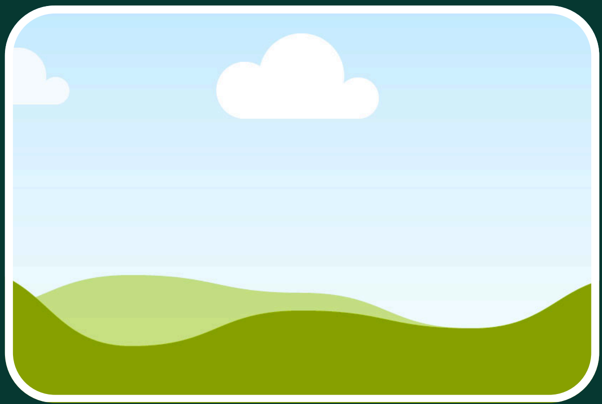
TEAM SUSTAINABILITY

- **FUNDRAISING**: Hosting workshops through a 'Build a Bot' events for upper elementary and middle school students
- **RECRUITMENT:** STEM interest meetings planned at community libraries and schools to recruite juniors
- **TRAINING SESSION FOR JUNIOR TEAM MEMBERS:** Planned programming, CAD and mech design workshops to support growth and development of junior team members

ENVIRONMENTAL PROTECTION

- **BIO-DEGRADABLE MATERIALS:** Used 3D printed PLA materials for CNC and robot parts. PLA derived from renewable organic sources.
- **RECYCLE METAL PARTS:** Repurposed materials to support rookie robot builds.
- **REDUCE CARBON FOOTPRINT**: Minimize Environmental Footprint of manufacturing: In-house CNC operation in the basement which cut transportation costs reducing carbon footprint
- **Emission Factor for Transportation**: Save 500 miles per month, emission factor = 0.5 pounds CO2 per mile. Calculation: 500 miles * 0.5 pounds CO2/mile = 250 pounds CO2 savings/month





Mentor Impact

MENTOR SEEKING

- Reached out via linkedln, school networks, family friends
- Reached out to FIRST alumni
- Sucessfully secured 6 mentors

KEY MENTOR LEARNINGS

- Guided the team to be agile, team organization, show respect and courtesy
- Highlighted importance of safety protocols
- Reinforced positive ethics and best UX/UI practices

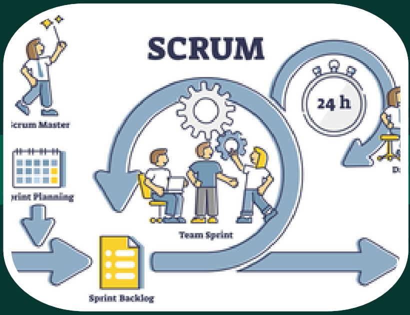
MENTOR STATS

95 Hrs In Person meetings + **30 Hrs** Virtual Meetings

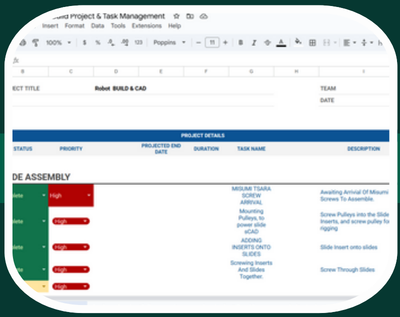
Total Mentor hours = **125 hrs**

AGILE

In **INTO THE DEEP**, our coach **Meghna Singh** and mentor **Ashish Mahajan** who work in the industry taught us how to use the AGILE DEVELOPMENT process to work together as a team. We implemented weekly Agile scrum meetings. The process allowed us to work more collaboratively and understand the MVP principles



Weekly Scrum Meeting



Task/Project Management

SAFETY FIRST

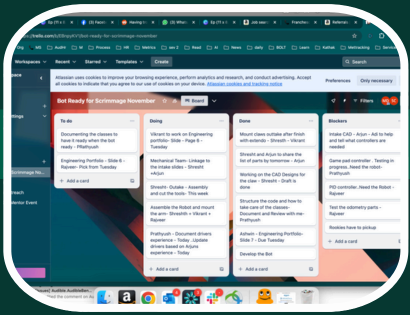
We reached out to **INDUSTRY MECHANICAL PROFFESIONAL Pallavi Lal** who reviewed and approved our CNC Safety setup. Ms. Lal also gave us the idea to create an enclosed environment for cutting. Since then, we have had over 30 hours of cutting both Aluminum, Carbon Fiber, and Polycarbonate.

CNC Safety Slides

Mentor Session

TEAM ORGANIZATION

We used real world tracking software's such as **TRELLO BOARD**. Through Trello Board, we are able to track tasks that we tracked on weekly standups. Through this connection, we are effectively able to track where we are as a team and what we can further push our progress and timelines.

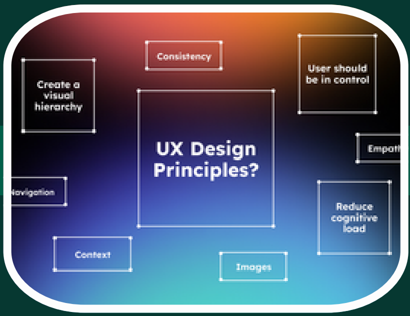


Trello Board

Example Scrum Board

UX PATTERNS

We reached out to **UX/ UI PROFFESSIONAL (Ex-CISCO), Dilasha Jain,** who provided us guidance on general UX design principles when **designing our WEBSITE**. In addition, for Software concepts we reached out to **Justin Cockburn, Software Engineer from Amazon-Audible** and discussed best practices for writing code and advantages of open source software.



UX Design Principles

CAD Cutting

Finance & Outreach

BUDGETING AND FUNDRAISING

FTC BUDGET FOR 2024-2025			
Earnings	**$11,650**	**Expenses**	**$11,000**
Member Dues	$9,000	New Robot Parts	10,000
Community Donations	$1,000	Registration Fees	$500
Home Depot	$150	Transportation costs	$200
Prime Achievers Donations	$1,500	Community outreach momentos	$300

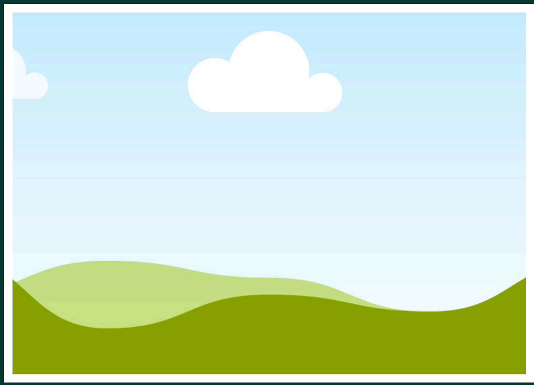
Focused on cost-effective purchases and optimizing resources

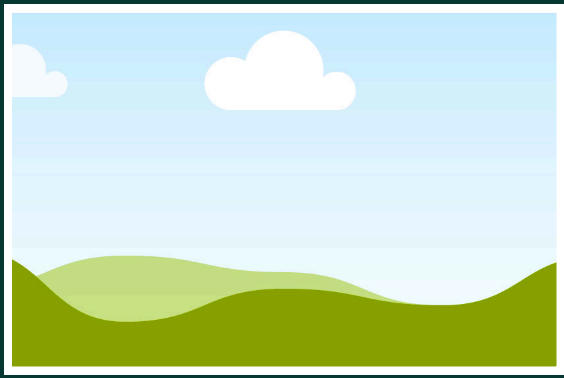
NC Machine		162(
S5 Remote Controllers		149.2
eam Registration		29
oBilda Strafer Chasis		461.9
ev control hub + Field Soft Tiles		697.2
otorola Phone		5
obi dremel sander		3
ble veis		3
orkbench		30
eld permimeter		823.8
anner	6/2/2024	10
yer		4
arts for robot from GoBilda (Screws & Bearings)	6/19/2024	32.2
obilda Bearings	6/19/2024	28.
TC-NJ Fees	9/3/2024	10
ndy Mark 2024 Season Kit	9/3/2024	658.0
oBuilda OdoMetery + Wheel	9/9/2024	400.5
xpansion Hub on Rev	9/9/2024	268.5
ervo Hub on Rev	9/9/2024	70.

Total expenditure sheet to maintain transparency and balanced budget

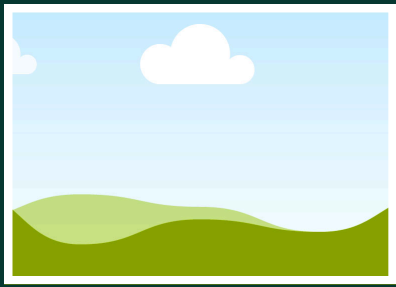
Reached out to a radio show and got an opportunity to be interviewed about FIRST and its core values. Broadcasted on FM 96.7, a radio channel which supports more than 1.2M listeners across US.

RADIO ZINDAGI

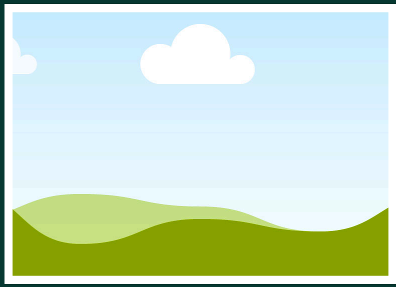




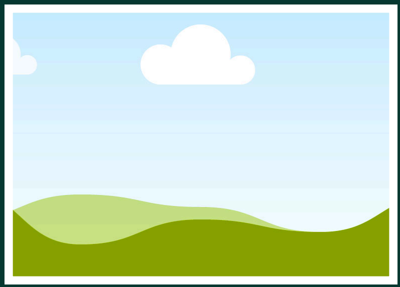
Efforts focused on promoting STEM, advocating FIRST CORE values across three main categories: Community, Underprivileged kids and Organizational events



STEM Booth at Mercer County Fair



Mentoring Kids at NJLEEPS for underprivileged kids



STEM Outreach at Bristol Myers Squibb

Outreach Continued

MERCER COUNTY

- Showcased STEM and FTC with robot demonstrations.
- Engaged diverse audiences, promoting STEM and FTC opportunities.
- Distributed flyers and presentations on STEM careers and FTC benefits.
- Networked for sponsorships, partnerships, and virtual lesson opportunities.
- Provided them insights on how they can open their own FTC team

Lions Club International

- **Over 46,000 local clubs**
- **More than 1.4 million members**
- **More than 200 countries**

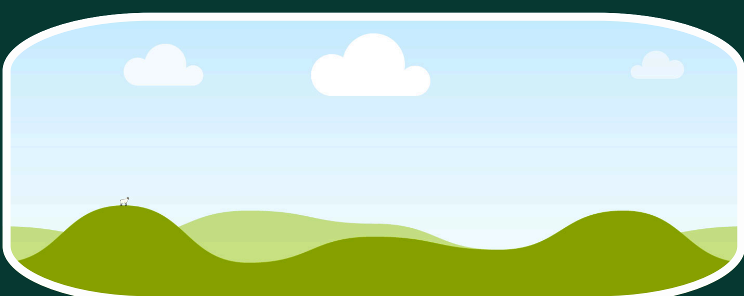
- Promoted STEM education and robotics among underprivileged youth.
- Shared our journey, introduced team members, and presented robotics progress.
- Highlighted FTC's mission, values, and impact on future STEM careers.
- Explored collaborations to expand STEM opportunities for underprivileged youth.
- Emphasized the partnership's role in preparing students for technological advancements.

BMS FTC ALPINE STEM EVENT

- Hosted a booth at the BMS offseason kickoff event.
- Shared insights on FTC hardware, robot building, and programming.
- Provided hands-on demonstrations to engage attendees.
- Answered questions to inspire interest in robotics.

ROBOCON EVENT NEW JERSEY

- Spread the word of FIRST and provided guidance on how to create a new team
- Created an obstacle course for kids to maneuver a robot through a defined path
- Provided hands-on robot demonstrations to engage attendees.
- Answered questions to inspire interest in robotics.



LESSONS LEARNED FROM OUTREACH FOR FUTURE EVENTS

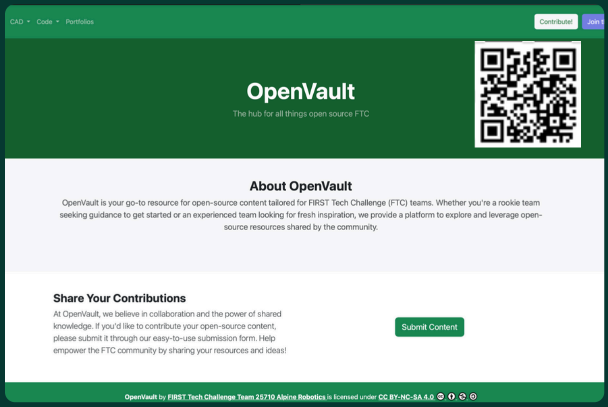
- Provide pamphlets (i) explaining the basic parts of a robot to kids for better understanding during demos (ii) Provide links on CAD, programming concepts, information on forming FTC and FLL teams.
- Follow up with current sponsors with progress updates on robot, and future plans for next season to continue dialogue and fund raising efforts

NJ LEEP

- **EDUCATED** middle schoolers on FIRST's goals and core pillars.
- **SHARED** the phases of starting a FIRST team.
- **MENTORED** NJ LEEP kids in robot design, architecture, and coding.
- **OFFERED** ongoing support for future team planning.
- **CONNECTED** students with coaches to establish their own team.

What is OpenVault?

Openvault, https://www.open-vault-ftc.org, developed by Alpine Robotics, is the **pioneering** and leading open-source platform dedicated to the FIRST Tech Challenge community. It serves as the largest **centralized repository** for publicly accessible resources, fostering collaboration and accelerating innovation through shared CAD designs, code libraries, and comprehensive engineering portfolios.
Our goal is to **make collaboration easier** by creating **a hub of shared assets**, helping teams **learn from each other.**

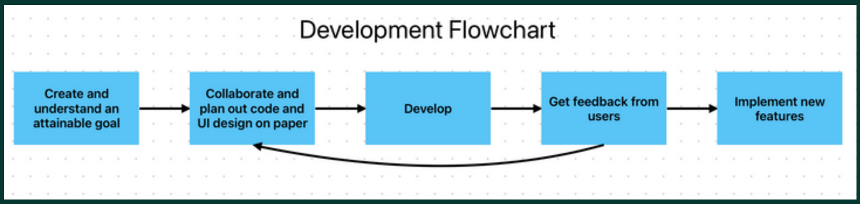


The Problem

As a **new team**, we **struggled** to find open-source content for inspiration, spending hours searching the internet and combing through countless forum posts. That's when we realized the need for a centralized database where teams could easily share and access resources. Seeing that **others faced the same challenge**, we got to work.

Development Process

Developing OpenVault required us to think through a **full stack of technologies**. We learned how to build a website, **end-to-end**, using **Python**, Flask, and the GitHub API for the backend and HTML, CSS, JavaScript, and **Bootstrap 5** for the frontend. We chose to host our code repository on **GitHub** as it offered the best resources for **collaboration**. Additionally, we decided to **host** using **Vercel** due to it's simplicity.

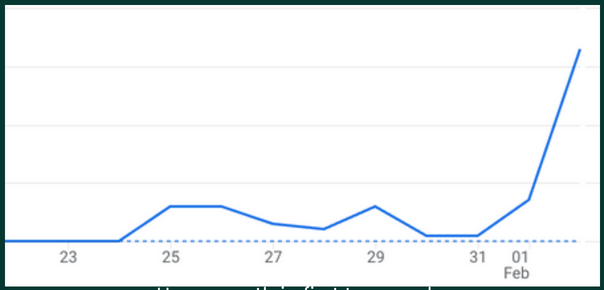


Impact

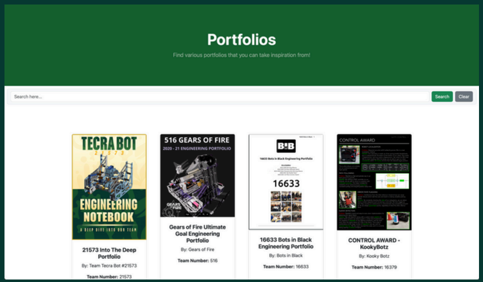
A team from Indonesia shared their excitement about seeing their designs featured internationally on our website. We're proud to support under-represented teams like theirs!

Fast Facts

- **First & Largest Open Source Hub In FTC History**
- **10+** Countries
- **15,000** Interactions
- **500** Active Users
- **4000** Page Views
- **All in two weeks!**



User growth in first two weeks



Portfolios Contributions from 15 teams

We are in countries like India and Australia

For The Future

Simplified Contribution Process:

- Instead of requiring a GitHub pull request, users will be able to contribute directly through a form on the website.
- The form will automatically generate a pull request, streamlining the process while maintaining moderation.

Enhanced User Experience:

- Improved filtering and search features to help users find relevant resources more easily.
- New ways for users to engage with posts, including a like feature.

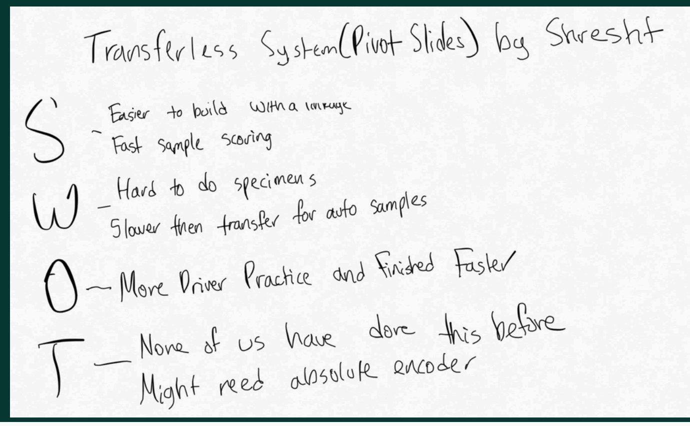
Game Strategy

Identify Key Objectives → Brainstorm → Determine match flow → Capability Alignment → Plan Alliance Strategy → Test Gameplay (During Agile Scrum)

Can go back to brainstorm at any time

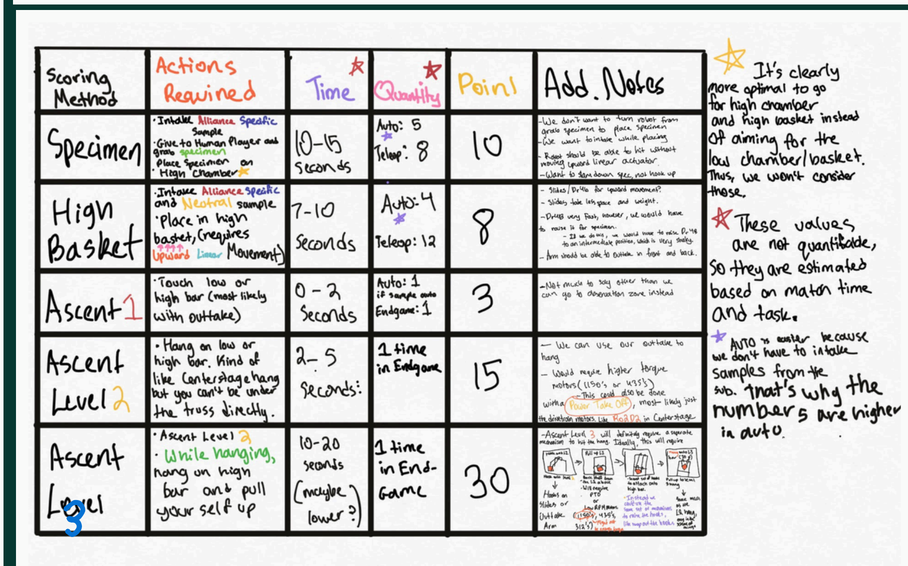
ROBOT DESIGN & GAME STRATEGY BRAINSTORMING

We brainstorm as a team while using **SWOT Analysis** to evaluate the strengths, weaknesses, opportunities, and threats of each idea. After gathering feedback, we refine the best concepts to match our goals.

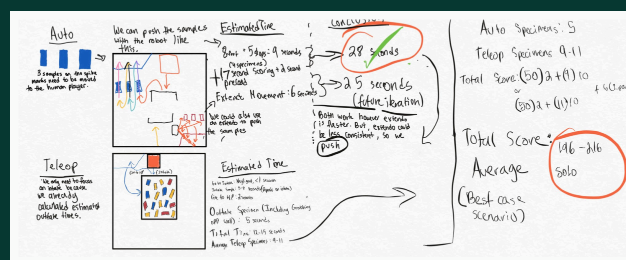


Breaking Down Game Strategy And Points

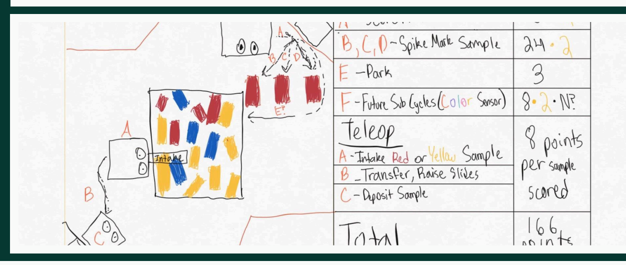
Game Breakdown



BEST CASE Specimen Side Estimated Score: 196-216

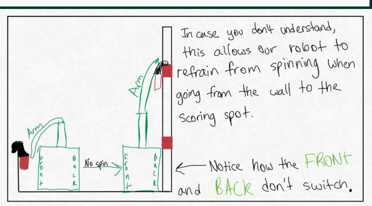


BEST CASE Sample Side Estimated Score: 166

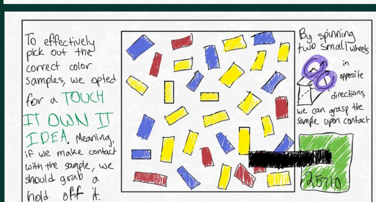


Robot Design Goals

Don't Turn To Place Specimen:
If we used our outtake to grab off of the wall, it would be unideal to turn the robot around to make the outtake face the chamber to place the specimen.

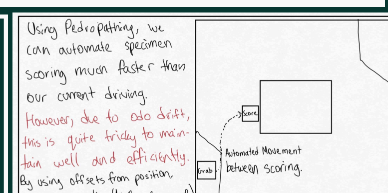


Touch it Own it Intake Mentality:
The samples in the submersible are very randomized, and grabbing a specific sample requires precise movement. The idea of touching a sample and "hooking onto it" was our main goal.

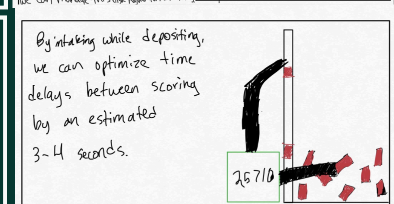


Idea Changes And Future Goals

Automatic Specimen Scoring:
Because there is no randomization or blocking between grabbing specimen and scoring, this process could be fully automated at the end of the match.



Intaking While Scoring Specimen's:
If we faced the submersible while scoring, we could intake inside the submersible while scoring. This would minimize time while scoring specimens by parallelizing depositing and intaking.



Finite Element Analysis (FEA)-Driven Optimization

Why Do We Need FEA?

As a **rookie** team with **limited resources**, we couldn't afford a **trial-and-error iteration driven** approach with physical prototypes. Instead, we **needed a solution that allowed us to test and refine our designs virtually**, reducing the need for constant rebuilding. This led us to rely heavily on simulation driven development, or (**FEA**).

What Is FEA?

FEA is a **computer-based simulation technique** used to **predict** how a design will respond to **real-world forces, such as stress, heat, vibration, and other physical effects**. The method breaks a design into smaller, finite elements and uses **mathematical models** & computer simulation to analyze their behavior.

How Did It Help?

- **Test Designs Virtually** – Simulating stress, strain, and performance eliminated the need to build every iteration.
- **Identify Weaknesses Early** – Pinpointing failure points helped us refine designs before manufacturing.
- **Optimize Material Use** – Structural analysis reduced unnecessary weight while maintaining strength.
- **Cost Benefit Analysis** – Avoiding multiple prototype builds saved us over **$1,000 in materials and manufacturing.**
- **Increase Confidence in Our Design** – Data-driven insights ensured our final design was reliable and efficient, and worked the first time.

Define Need → Design → Analyze → Prototype → Validate

Our FEA Based Process

Intake

Define Need

Game Adaptation: We want the ability to pick up samples at any angle, following the **Touch is Own It Mentality**. (1)

Reliability First: Focused on minimizing in-game failures for consistent performance.

Precision Fabrication: Used 3D modeling software to ensure accuracy in manufacturing.

Design

Option 1

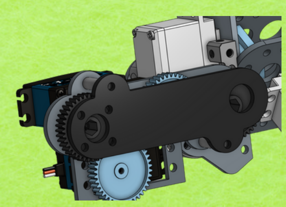
Standard - Geometrically aligned intake

Advantages
- Long enough to reach the end of the submersible from a given side
- light intake made of PLA

Tradeoffs
- Very flimsy, so no rigidity
- High maintenance due to 3D-printed parts

Option 2 (2)

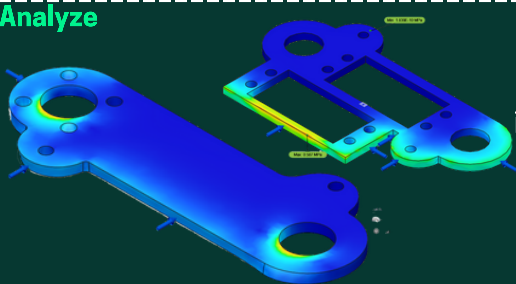
Advanced - Custom Intake



Advantages
- Highly compact and light from CF
- increased DoF
- Smaller and faster

Tradeoffs
- High Servo count (sacrifice battery power)
- Less maneuverable.

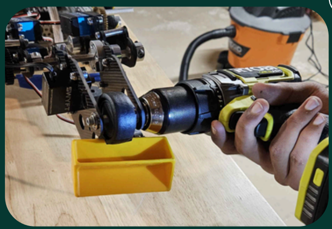
Analyze



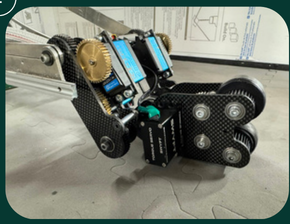
We conducted stress test simulations to evaluate the strength of our intake design. Applying a 200N impulse to the top allowed us to identify critical areas for reinforcement. After simulating both materials, we decided to **BUILD** the intake with **CARBON FIBER** instead of traditional **aluminum**, as it offers a lower weight and greater stress capacity. (3)

Prototype

(1)

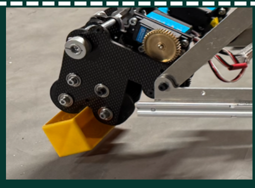


(2)



- **Fabrication—**Cut carbon fiber in-house using our X-Carve CNC (4)
- **Assembly—**Started to use metal parts to assemble the parts together in order to create a more cohesive intake
- **Testing—**Used a drill to spin wheels to test the intake's functionality

Validate



After **measuring** several parameters on the intake such as the **retraction** and **extension time**, to be used in code; while stress testing, we recognized that the **intake wrist is slightly wiggling**, something that can be **fixed with counter springing in the future.** (5)

Outtake

Define Need

1

Game Adaptation: Our outtake needs to have the ability to score from both the front and the back.
Reliability First: Our outtake should be reliable to withstand long hours of testing and competition
Precision Fabrication: Used 3D modeling software to ensure accuracy in manufacturing.
Durability & Efficiency: Engineered a robust and effective robot for competition.

Design Options

2

Option 1
Standard Non-Geometrically Altered Part

Advantages
Less likely to have material failure, meaning that the Outtake is less likely to deform under impact. Opens us up for hang in the future.

Tradeoffs
Higher weight, which will increase overall weight of the robot for fast movement

Selected

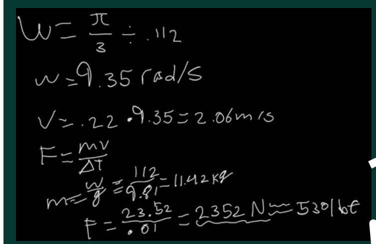
Option 2
Standard Geometrically Pocketed Part

Advantages
Less weight, way easier for slides to raise because of the weight difference. Almost as light as carbon fiber.

Tradeoffs
More likely that the outtake can break due to it being much more fragile.

Analyze

3



Calculations intended for finding the force that our end effector would leave when hitting an obstacle
Factoring in **gravity** and the **natural forces**
Factored in servo speed and gear ratios.
These calculations were later inputted in the simulations for results.

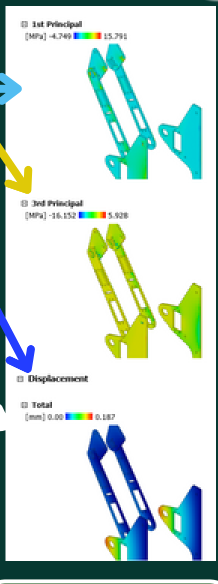
A Von Mises FEA (Finite Element Analysis) simulation evaluates material failure or yield by calculating the Von Mises stress, which determines whether a material will plastically deform under complex loading conditions.

Your First Principle Simulation ensures structural stability under force, while your Third Principle Simulation ensures uniform stress distribution

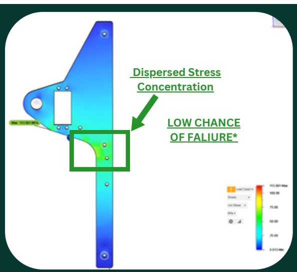
Total displacement in the x, y, and z directions represents the overall movement of a point in space, calculated by summing the individual displacements along each axis due to applied forces or boundary conditions.

Safety factor represents the ability and chance for a part to break under pressure, scale of (Highest chance of failure) 1- 15 (Lowest)

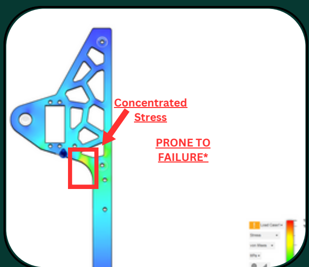
Name	Minimum	Maximum
Safety Factor		
Safety Factor (Per Body)	15.00	15.00
Stress		
von Mises	0.00 MPa	15.494 MPa
1st Principal	-4.749 MPa	15.791 MPa
3rd Principal	-16.152 MPa	5.928 MPa
Normal XX	-15.346 MPa	15.081 MPa
Normal YY	-4.765 MPa	6.684 MPa
Normal ZZ	-10.952 MPa	14.167 MPa
Shear XY	-1.568 MPa	1.902 MPa
Shear YZ	-1.602 MPa	2.059 MPa
Shear ZX	-7.134 MPa	7.333 MPa
Displacement		
Total	0.00 mm	0.187 mm
X	-0.006 mm	0.004 mm
Y	-0.187 mm	0.187 mm
Z	-0.005 mm	0.004 mm



Simulation Diagram of stress, displacement and principles



Stress Analysis on **Unpocketed** Custom Part **via** Fusion 360



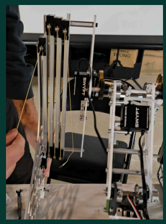
Stress Analysis on **Pocketed** Part **via** Fusion 360

Results and Lessons Learned

FEA Stress Simulation: We ran a stress simulation using Finite Element Analysis (FEA) on our outtake plates to analyze their performance under applied forces.
Analysis Pocketing: During simulations pointed on the left, we realized that pocketing on the plate, created areas of weakness that would result in failure.
Force Dispersion in Non-Pocketed Plate: The non-pocketed plate, on the other hand, was more effective at dispersing shear forces, as demonstrated by the 1st Principle Simulation, ensuring a more balanced force distribution across the structure.
Third Principle Impact: The Third Principle Simulation showed that the non-pocketed plate experienced more uniform stress dispersion, reducing localized strain and preventing unexpected failures.
Conclusion: **Based on our findings**, the non-pocketed plate **demonstrated superior strength** in force distribution, making it the **better choice** for our application.

Prototype

4

①

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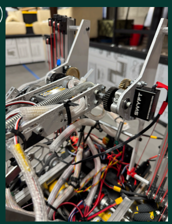


- **Fabrication**—Cut aluminum in-house to create parts
- **Assembly**—Started to use metal parts to assemble the parts in order to create a more cohesive intake
- **Testing**—used a servo tester to test the movement in the arm
- **Programming**—Starting to get values for arm and “wrist” mechanism

Validate

5


After **measuring** several parameters on the intake such as the **retraction** and **extension time**, to be used in code; while stress testing, we recognized that the **intake wrist is slightly wiggling**, something that can be **fixed with counter springing in the future.**

Drive-Base Overview

Design Goals

- **Lightweight & Rigid Frame** – Use materials like aluminum, carbon fiber, or reinforced polycarbonate to ensure strength without adding unnecessary weight.
- **Compact Design** – Keep the chassis height minimal to lower the center of gravity and improve stability during fast maneuvers.
- **Balanced Weight Distribution** – Place motors, batteries, and electronics strategically to avoid tipping and improve handling.
- **Easy Access to Electronics and Wiring** – Design compartments or panels that allow for quick adjustments and maintenance of electrical components.
- **Ground Clearance** – Ensure the chassis height allows smooth operation over FTC field elements while preventing unnecessary drag.
- **Minimized Mechanical Backlash and Play** – Design precision-fit components and proper belt tensioning to avoid drivetrain slack and maintain responsive controls.
- **Efficient Integration with Programming** – Provide dedicated mounting points for encoders, IMUs, and other sensors to improve control accuracy, minimize programming margin for error for quick-turn prototyping

Design Tradeoffs & Lessons Learned

- **Weight vs. Durability** – Using lightweight materials like carbon fiber reduces weight but may increase cost and complexity compared to aluminum.
- **Compactness vs. Accessibility** – A lower chassis improves stability but can make electronics and wiring harder to access for repairs.
- **Weight Distribution vs. Modularity** – Optimizing balance can limit flexibility in component placement for future upgrades.
- **Ease of Access vs. Structural Integrity** – Removable panels simplify maintenance but may compromise frame rigidity.
- **Ground Clearance vs. Stability** – Higher clearance helps with field obstacles but raises the center of gravity, reducing stability.
- **Backlash Reduction vs. Serviceability** – Tighter tolerances improve drivetrain response but can make assembly and maintenance more difficult.
- **Sensor Integration vs. Design Complexity** – Mounting encoders and IMUs improves control but requires additional space and design refinements.

Iterations & Goals

Motor Plate

V1

Evaluated: Has minimal Structural Integrity and does not have good hole to outline clearance at < 0.5 mm.

V2

Lesson Learned: Created a more rigid and structured piece with an increased amount of clearance at ≥ 1.5 mm.

Design Target

We want our motor plate to be strong but lightweight, ensuring a precise drivetrain while staying durable.

Drive Train Pulleys

V1

Evaluated: Pulley was not compatible with Wheel Configuration and not high enough in teeth to produce high torque

V2

Lesson Learned: Custom pulley matches mecanum wheel pattern and has high teeth count ensuring higher output torque

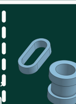
Design Target

We want our drivetrain pulleys to provide efficient power transfer with minimal slippage, balancing strength, weight, and ease of maintenance for optimal performance.

Drive Train Tensioners

V1

Evaluated: Was not adaptable to our needed environment, lacked customization and degrees of freedom on the belts



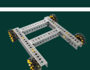
V2

Lesson Learned: High adaptability to fit in any part of the robot that would need tensioning, highly modular and has more degrees of freedom

Design Target

We want our drivetrain tensioners to maintain consistent belt tension, ensuring smooth power transfer while being easy to adjust and have good degrees of freedom

Powertrain



V1

Evaluated: Was geared, and was steel which lead to a greater mass reducing speed, was not modular with other vendors

V2

Updates: Modular with various vendors, 25% weight reduction, belted, greater efficiency, resulting in friction and noise suppression.

We want our powertrain to deliver high torque and efficiency with minimal energy loss while remaining lightweight, reliable, and easy to maintain.

Design Target

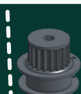
This design should minimize slippage, maintain consistent tension, and integrate seamlessly with the overall system for optimal performance and ease of maintenance.

Design Target

Outtake Pulleys

V1

Evaluated: Retraction and Extension rigging were on the same pulley leading to skipping and reduction in power



V2

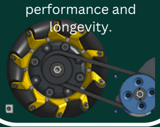
Updates: Separates Retraction and Extension Pulley's Into Two Different Pulleys Resulting in Little Skipping and Efficient Power Transfer

Drivetrain Overview

A

Drive Pulleys (18:22 Teeth)

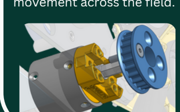
Made to ensure maximum belt engagement, reducing slippage and improving power transfer efficiency. Features lightweight material construction to minimize rotational inertia while maintaining durability. The custom design also incorporates side flanges to keep the belt aligned under high-speed operation, ensuring consistent drivetrain performance and longevity.

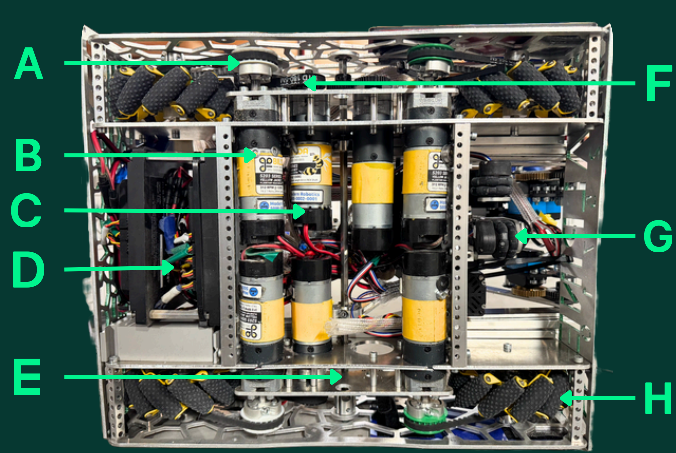


B

312 RPM Drive Motors

Selected over **the standard 435rpm motor** ,ensuring an optimal balance between acceleration, top speed, and pushing power. These motors, paired with our custom **18:22** drive pulleys, our drivetrain outputs approximately **86 kg-cm of torque**, allowing for strong defensive play and resistance against pushing forces, while still enabling agile and responsive movement across the field.





H

Mecanum Wheels

104 mm Mecanum wheels chosen over the 96 mm wheels for better traction, increased ground clearance, and improved stability. Their larger size allows for smooth omnidirectional movement, enabling the robot to move in any direction—forward, backward, sideways, or diagonally—without altering its orientation.

G

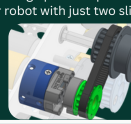
Odometry Setup

Our GoBilda 4-bar odometry system, featuring two odometry pods, tracks the robot's movement for precise localization. By integrating GoBilda PinPoint, which adds a second IMU, we achieve the most accurate position headings, enhancing the robot's ability to maintain precise orientation. This dual-IMU setup ensures reliable navigation, improving autonomous performance and positioning accuracy

C

1150 RPM Slides Motors

After evaluating various options, we selected this configuration to achieve an output of 30 kg-cm of torque from both motors combined, giving us the strength needed to lift the robot reliably. The 17-20 tooth gearing optimizes power delivery and lets us hang our robot with just two slide motors.



D

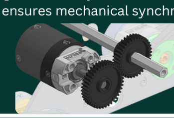
Control Hub and Wiring Setup

Our horizontally mounted Control and Expansion Hubs ensure compact wiring and easy access. The Servo Hub provides a stable 6.0V output, boosting servo torque and responsiveness for a faster, more reliable outtake. This setup maximizes efficiency, ensuring consistent performance throughout matches.

E

60RPM 40:36 Gear Ratio Extendo

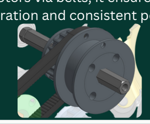
Our 36:40 gear ratio combined with a 60 RPM motor delivers an output of 133 kg-cm of torque, providing the necessary strength for demanding tasks. This gear-driven system, mounted on a single shaft, ensures mechanical synchronization



F

Outtake Slides Shaft

The outtake slide shaft, integrated into the chassis, synchronizes retraction and extension pulleys for simplified programming. Driven by outtake motors via belts, it ensures smooth, efficient operation and consistent performance.



Mechanical - Intake Mechanism

Design Goals

- **Lightweight Carbon Fiber Construction**—Reduces overall robot weight while maintaining strength and durability.
- **Servo-Powered Actuation**—Provides precise control over arm movement with efficient power usage.
- **Planetary Gear System**—Increases torque output for lifting or handling heavier game pieces without overloading the servo.
- **Spinning Intake System with Wheels**—Quickly grabs game pieces with rotating wheels for effective intake.
- **Advanced Gearbox**—Optimized for efficient power transfer, balancing speed and torque for the intake arm's motion.
- **Compact Design**—Small form factor that minimizes space usage, enabling efficient robot packaging.

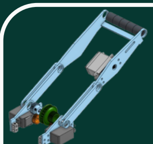
Design Tradeoffs & Lessons Learned

- **Weight vs. Strength (Carbon Fiber vs. Aluminum)—Carbon** fiber reduces weight for better mobility but may compromise toughness and increase cost compared to aluminum.
- **Compactness vs. Power (Servo vs. Motor) –** A compact servo-powered system saves space but may not provide as much power as a motor, limiting the intake arm's capacity for heavy game pieces.
- **Precision vs. Speed (Planetary Gear vs. Direct Drive)**—The planetary gear system offers high precision but can reduce the speed of the intake arm compared to a direct motor drive system.
- **Torque Efficiency vs. Actuation Time (Advanced Gearbox vs. Simple Gearbox) –** An advanced gearbox provides better torque transfer but might increase actuation time or complexity compared to a simplexr design.
- **Durability vs. Weight (Lightweight Carbon Fiber vs. Impact Resistance) –** The lightweight carbon fiber reduces overall robot weight but may break or crack under heavy impacts, affecting durability.

Iterations & Goals

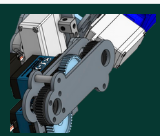
Intake Arm

V1



Evaluated: Our first intake arm iteration was too long and heavy, preventing the servo from rotating it effectively. While the design seemed viable in theory, its weight and length made it impractical for real-world fabrication, highlighting the need for a more balanced approach.

V2

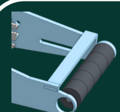


Lesson Learned: The final intake arm is compact and lightweight, crafted from carbon fiber. It utilizes a planetary gear system for faster rotation around a fixed point and includes a "wrist" mechanism for added precision and flexibility.

Design Target
We want our intake arm to be small and compact, ensuring high stability and efficiency

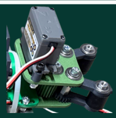
Intake End Effector/Claw

V1



Evaluated: Our first end sample obtainer was very fragile and would not be able to withstand competition play. Additionally, this end effector was not effective at picking up samples during testing, with an 18% grab rate in realistic scenarios. was too flexible as it was designed with PLA.

V2



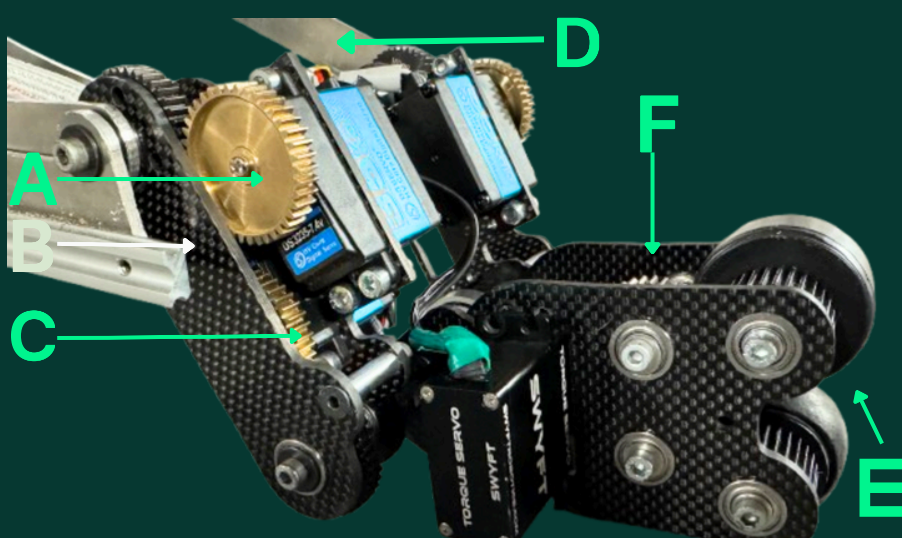
Lesson Learned: This intake mechanism utilizes a claw feature. Was not sustainable as it was made out of PLA and could not withstand competitive play. The right geometry to pick up samples was not designed in this claw. Was too heavy to be used by Intake arm.

V3

Lesson Learned: This final intake mechanism is custom CNC'ed out of carbon fiber. It is very lightweight and durable (effective in competition play). Additionally, the rotational wheels allow for seamless sample grabbing with almost no effort, making it very efficient

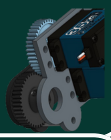
Design Target: aiming for a very efficient pickup that is very accurate and seamless. We wanted a lightweight, yet durable model that would be able to sustain competiton play

Intake Overview



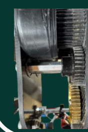
A
Arm Servo

The servo powering the 1:1 gear ratio system rotates around a stationary gear, which in turn drives the entire arm's movement. This setup allows for **highly efficient** operation, with the servo providing **precise control** and **quick motion**. Thanks to its design, the travel time for the intake is **under 0.25** seconds, ensuring rapid and responsive action when handling game elements. The combination of the gear system and servo speed enables **seamless performance**, critical for **fast-paced tasks**.



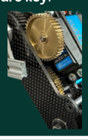
F
Advanced Intake Gearbox

The **advanced gearbox** in the end effector features a 40:22:20 gear ratio for high-speed intake, ensuring fast and efficient performance. Each gear is strategically mounted on separate shafts, allowing for independent movement and preventing misalignment or skipping. This setup maximizes efficiency, durability, and torque distribution, while maintaining perfect synchronization. The optimized design enhances responsiveness, delivering smooth, reliable operation even under high-speed conditions, making the intake system highly effective and dependable.



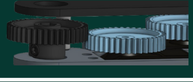
B
Custom CNC'ed Carbon Fiber

The 83.8 mm carbon fiber arm is a **compact yet powerful** component, built to support a torque servo producing **50.8 kg of torque**. Its **carbon fiber** construction offers an exceptional **strength-to-weight ratio**, keeping it lightweight while maintaining **rigidity** and durability. This reduces strain on the servo, **enhancing efficiency**, precision, and responsiveness. Designed for compact applications, the arm ensures reliable performance without adding **unnecessary weight**, making it ideal for robotics and automation where **strength and agility are key**.



C
Geared "Wrist" Mechanism

The "wrist" intake features a **high-speed** gearbox with precisely placed gears, using a 40:40 ratio for **rapid** and **efficient** operation. Each gear is strategically spaced on separate shafts to **prevent skipping** and ensure smooth **torque transfer**. This design maximizes speed and reliability, making the intake system both **fast** and **consistent** under demanding conditions.



D
Linkage Driven Horizontal Extension

The linkage-driven horizontal extensions are powered by a 40:36 gear ratio, driven by a 60 RPM motor. Mounted on a shaft, the system operates in **under 0.5 seconds**, providing quick and efficient extension. The gear setup **ensures smooth** and **reliable movement**, making it ideal for **fast, precise adjustments**.

E
Custom Carbon Fiber Spin-Intake

Our spinning wheels are designed to fit perfectly between the edges of the sample for optimal intake. Each wheel has two custom 3D-printed gears and a circular component for a seamless grip. Rubber tape enhances traction, ensuring secure handling. The wheels spin asynchronously, spaced to create an efficient intake process that guides the sample smoothly into the system, maximizing reliability and consistency.

Mechanical - Outtake Mechanism

Design Goals

- **Solid and Structured Frame** – Work with Materials such as aluminum and PLA Carbon Fiber to keep it lightweight and rigid.
- **Balanced Weight Distribution**—Place servos and electronics strategically to avoid excessive weight at the end of the end effector.
- **Easy Access to Electronics and Wiring**—Design Placement of Servos such that access is easy and fast.
- **Keep Symmetry with Subsystems**—Ensure the mechanism is placed in the right geometrical area for an efficient transfer and position.
- **Minimized Mechanical Backlash and Play**—Design pulley and Arm such that there is no skipping and precise fitting and simulations in CAD are done to ensure accuracy.
- **Efficient Performance**- Outtake able to intake specimens as well as depositing it. .

Design Tradeoffs & Lessons Learned

- **Weight vs. Durability (PLA Components)**—**PLA is** lightweight and durable but may be more brittle under impact compared to other materials like nylon or polycarbonate.
- **Precision vs. Power (Servo-Powered Pulley)**—**A servo** allows for controlled movement but may struggle with heavy loads compared to a motor-driven system.
- **Countersprung Arm vs. Non-Countersprung Arm**—A countersprung arm reduces strain on the servo and improves energy efficiency but adds complexity and requires tuning. Without a counter-spring, the servo must work harder, increasing power draw and wear.
- **Compactness vs. Torque (Wrist Mechanism)** – A smaller, servo-powered wrist saves space but may limit torque, affecting grip strength and rotation speed.
- **Simplicity vs. Adjustability (Pulley-Driven System)**—**A pulley-driven** mechanism simplifies actuation but may limit real-time adjustments compared to a direct-drive system.
- **Stability vs. Speed (Wrist Control)**—**A more** rigid wrist provides better stability for precise placement but can slow down movement compared to a looser, more flexible joint.

Iterations & Goals

Outtake Mount

V1

Evaluated: The outtake holder was not rigid enough to support the weight of the outtake arm. Clearance for the servo plate was too thin to support its structure over time.

V2

Lesson Learned: Holder has higher surface area, enough to hold the weight of the arm, and the servo pushed to the right to meet our **design goals**

Design Target

We want our outtake holder to be a very rigid and strudy structure with lzero flex when weight is distributed

Outtake Arm

V1

Evaluated: Arm is too heavy to be turned by servo. Arm did not have mechanisms for the degree of freedom that we wanted.

V2

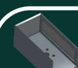
Lesson Learned: The outtake arm now features servo placement for extra DoF by enabling a "wrist" mechanism. Strategized pocketing to reduce weight and keep structure.

Design Target

We want our outtake arm to be as light as possible while maintaining rigidity.

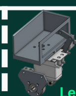
Outtake Claw

V1



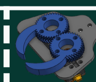
Evaluated: The bucket lacked a process to keep the sample in place and was too large to fit in our subsystem. FInally, it lacked the proper geometry to obtain a sample

V2



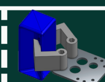
Lesson Learned: Created a servo-powered actuator to keep sample pushed against its own wall to be kept in place. Still, was too large to fit in our subsystem

V3



Lesson Learned: Created a smaller system that fits inside the subsystem. More efficient power to sample as gears help produce 1:1 torque. Was metal, so became too heavy

V4

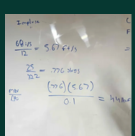


Lesson Learned: Claw geometry replicated sample edges to ensure proper grabbing position. Claw plate structured to be 3D Printed to ensure structure while being lightweight

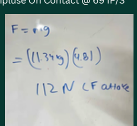
Design Target

We want our outtake claw to be able to pick up samples and specimens. Additionally, We wanted to keep it as light as possible while maintaining rigidity to ensure a speedy process also while maintaining accuracy.

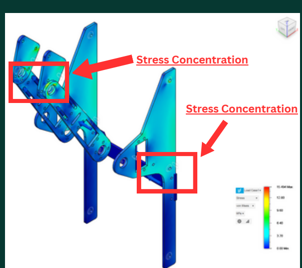
Math, Stress Simulations & Adaption



Impluse On Contact @ 69 IP/S

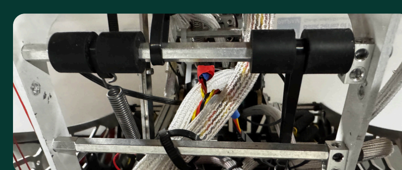


Constant Hang Force



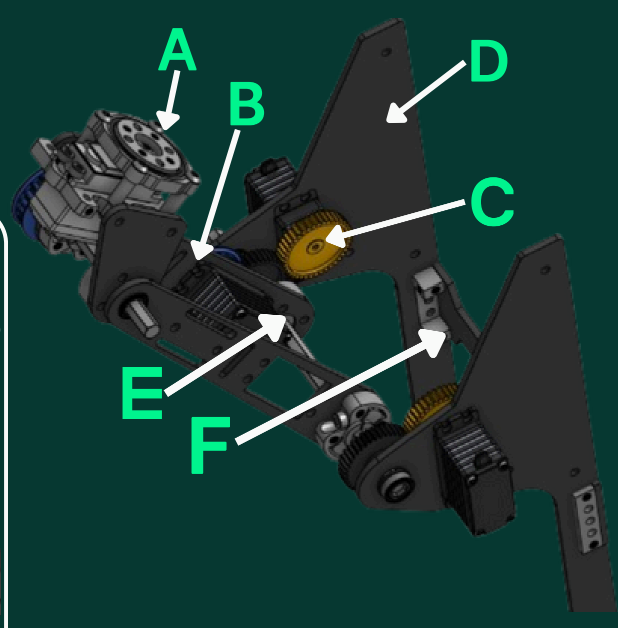
Outtake Impact Stress Simulations

- Identified the need for the outtake to handle dynamic loads, including impact shock from contact and the weight of the robot when hanging.
- Utilized computer simulations to assess the design's capabilities and minimize resource use by identifying areas for reinforcement.
- Applied impulse calculations and force distribution analysis to simulate the outtake's behavior under hanging conditions.
- Input precise Newtons of force on the subcomponents to analyze stress concentrations.
- Identified key areas of high force to reinforce for optimal performance.
- Optimized the design by strategically reinforcing sections where stress was highest, ensuring the outtake could handle dynamic loads without failure.



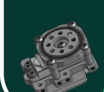
After identifying structural instability in the arm through simulations, we replaced the inadequate crossbar with steel shafts, securing them at the highest stress points. This fixed the torsion force issues in the slides.

Outtake Overview



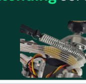
A Swivel Servo Mechanism

The **high-speed** swivel servo, mounted on a pillow block to dissipate load, delivers 40 kg of torque for **smooth** and **precise** sample rotation. Its **fast actuation** ensures **quick** adjustments, **optimizing positioning** during gameplay.



E Counterspringing

Our outtake arm is counter-sprung from the leading shaft to reduce servo strain and **improve efficiency**. This design minimizes lifting force, making depositing **smoother** and **extending** servo longevity.



B Pulley "Wrist"

A servo rotates a 20T pulley, which is belted to another 20T pulley, transferring motion to a shaft that controls the end effector. This 1:1 ratio ensures **consistent speed** and **torque**, allowing for **smooth** and **precise** rotation. The belted system **reduces backlash** while maintaining **efficiency**, ensuring reliable performance during operation. With controlled actuation from the servo, the end effector can **quickly** and **accurately** adjust to different positions as needed.

C Arm Servo

The Swyft torque servo powers a 40:40 gear system, **rapidly moving** the outtake arm with precision. Its high torque and 1:1 ratio ensure fast, controlled motion, enabling quick and **efficient** outtake cycles for smooth gameplay.

F Crossbar

The crossbar on our outtake structure provides essential rigidity and stability. It prevents flexing, distributes forces evenly, and ensures smooth, reliable operation under stress. By reinforcing the overall structure, it helps the **sustainability** and efficiency throughout use.

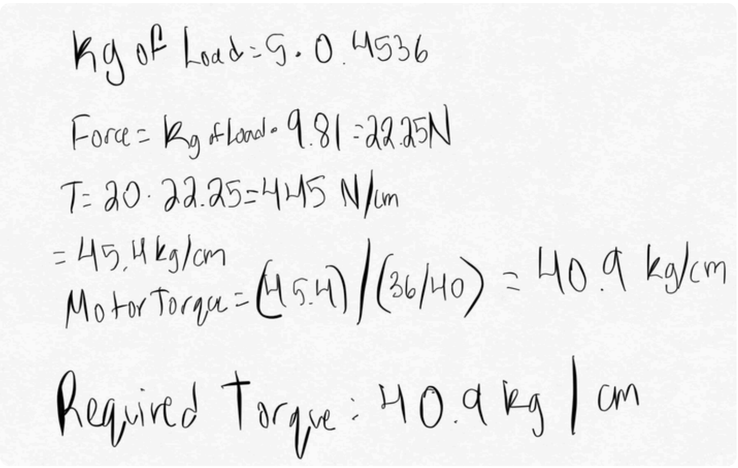
D Outtake Structure

Our Outtake Plate, mounted on Misumi slides, ensures smooth, **precise** motion. Made from rigid aluminum, it withstands high loads while maintaining alignment. With servo holes and shaft mounts for efficiency, its design maximizes reliability and performance.

Engineering - Math

We needed a lot of **math** to design our robot because it was important to ensure that our designs would work before we built them. For more math, see **Tablet Notes**.

Calculating Torque For Linkage Deployment:

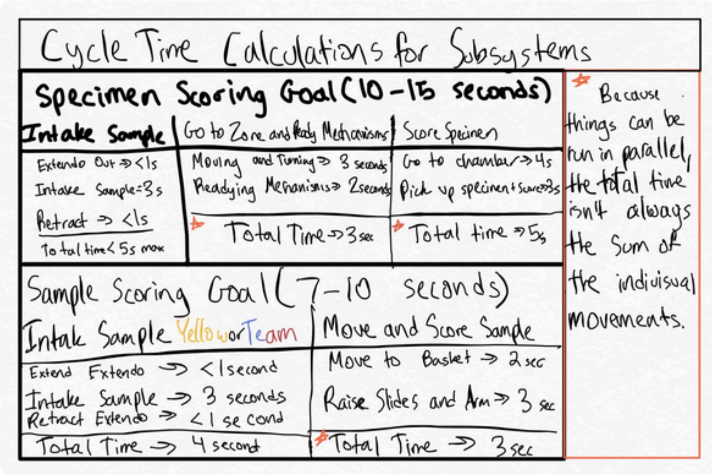


How much force is required to extend our linkage in 0.4 seconds?

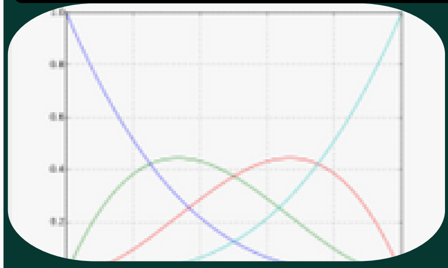
Our robot's linkage is geared **40 driver to 36 driven** with a load of **5 lbs**. We aimed to extend the full linkage in less than **0.5 seconds**, and determined that we would need **40.9** kgs of torque, shown above, so we decided to use a 133kg motor, to account for friction and linkage deploy.

Cycle Time Calculations:

As shown earlier(page 3), we aimed to receive **8** specimens or **12** samples during *TELEOP*. To achieve this, we needed to calculate the **exact** time frame that each subsystem has to move in.

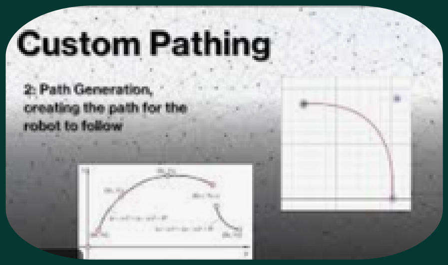


Lessons Learned & Mentoring

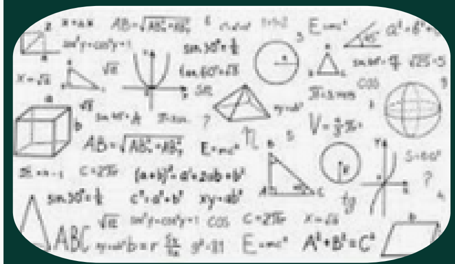


Bezier Curve

Pedropathing (Connect) : Logan Nash is the developer of pedropathing. We reached out to him for support. Logan helped us tune our robot for faster speeds, which allowed us to hit a 5 + 0 autonomous speed in 30 seconds.

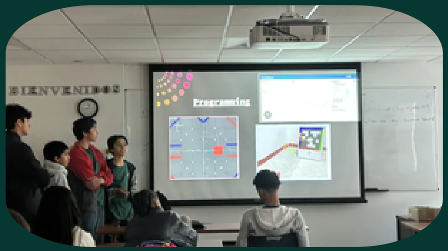


Custom Pathing



Geometry and Design principles

Student Outreach Impact (Mentoring): Our experience at NJLEEPS helped students connect geometry with real-world applications, as they could see how basic geometric concepts, like angles and coordinates, were crucial to making the robot function as intended. By showing how math helps control movement, we sparked interest in both robotics and the math needed to make it all work.



NJ Leeps Tutoring

PROGRAMMING WORKFLOW

Define what needs to get done → Collaborate with mechanical on an effective design that would make sense to program as well → Organize our code on paper and write down the order in which things will happen → Implement the right libraries and begin to code → Test code and coordinate with drive team to make sure controls work well → Keep iterating and improving based on feedback and testing

IN THE PAST

LACK OF OF STRUCTURE

- Used many conditional statements, leading to cluttered and unorganized code.
- Relied on complicated multithreading for sequencing.
- Increased error risk due to complex code structure.

OUTTAKE

- Outtake movement was extremely rash.
- Collided with the intake while coming down.
- Risked breaking due to excessive force.

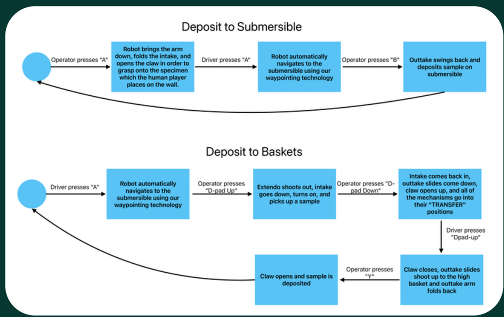
LACK OF WRIST MOTION

- Wrist coding revealed linkage limitations.
- Original design lacked needed motion.
- Required redesign for full movement.

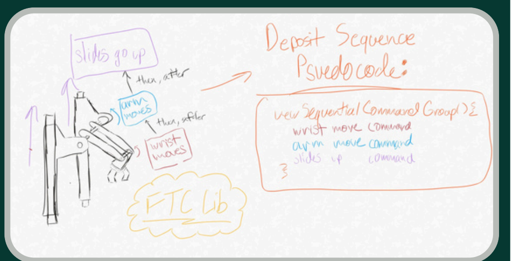
INACCURATE POSITIONS

- No precise control over mechanism positions.
- Relied on inaccurate RUN_TO_POSITION.
- Needed a more reliable positioning method.

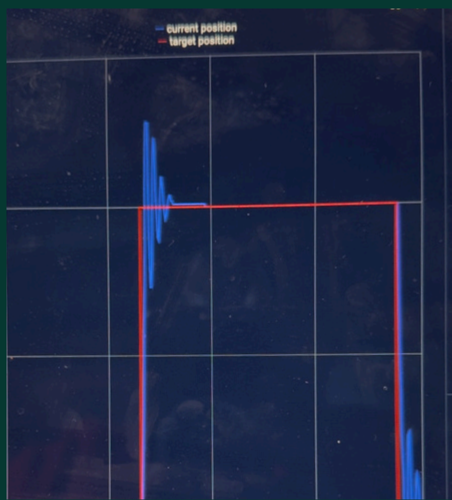
APPLICATIONS



State machine diagram of our robot



FTC Lib Psuedocode



Tuning our PIDF controller for maximum accuracy

NOW

FTC LIB

We adopted FTC Lib to control our mechanisms. This allowed us to...

- Control mechanisms with "**commands**."
- Run commands **sequentially** or in **parallel**
- Simplified control by binding commands to button presses
- Efficient control of state machine

3D PRINTS>ALUMINUM

- Collaborated with the mechanical team to switch from aluminum to 3D-printed parts for the wrist and swivel, reducing weight.
- Incorporated intermediate positions to slow the descent.
- Eliminated slamming by controlling descent speed.

WRIST MOVEMENT

- Switched to a belted design.
- Gained the necessary degrees of freedom.
- Improved accuracy in obtaining values

PIDF CONTROLLER

- Implemented a P.I.D.F. controller for mechanism control.
- Used encoder feedback from motors for accuracy.
- Achieved precise positioning on the robot's extendo and outtake slides.

Programming - Autonomous

AUTONOMOUS PATHING

In September, we learned of **Pedro Pathing**, which was a different way to run generate paths then what we normally used, **Road Runner**. To choose, we extensively tested both. Here's what we found.

RoadRunner | **PedroPathing**

RoadRunner:

Utilizes motion profiling to generate paths. This means that even if the path isn't as accurate, it will still be in each position at the right time

Paths are defined by trajectories generated with tuned motion profile systems.

Both:

They both have visualizers to easily simulate and create paths

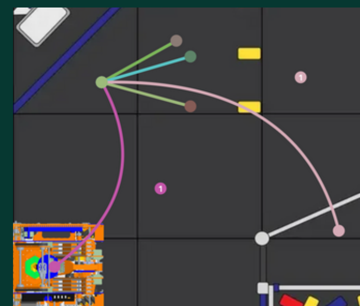
Use a PID to correct

PedroPathing:

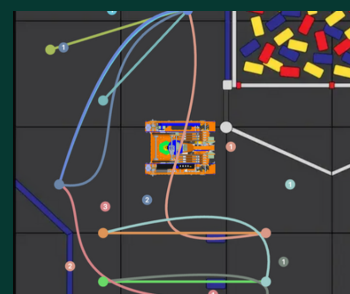
Prioritizes speed over anything else, aiming to reach maximum velocity of robot.

Uses Bezier Curves for pathing, because the paths aren't motion profiled they can be run efficiently in TeleOp.

Has a TeleOp program which accounts for centripetal force to smoothen turns.



Our 4 sample autonomous path

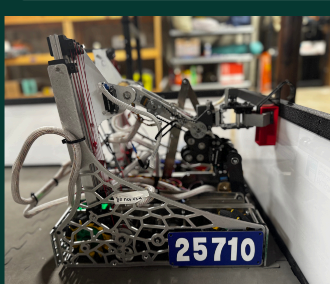


Our 5 specimen autonomous path

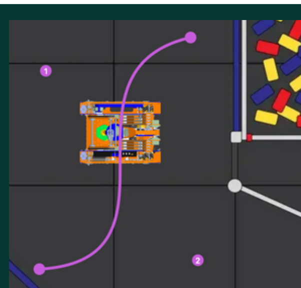
We ultimately chose PedroPathing because it's faster, easier to tune, and improves our TeleOp.

WAYPOINT BASED AUTOMATED SCORING

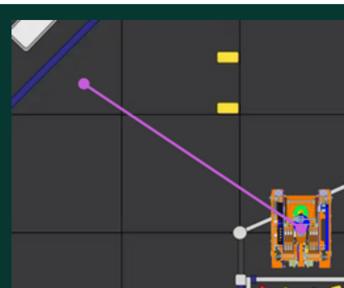
To improve speed during **TeleOp**, we incorporated **Automated Specimen Scoring** to improve our cycle times. We autonomously move between the observation zone and submersible, drastically improving our cycle times and taking stress off our drivers



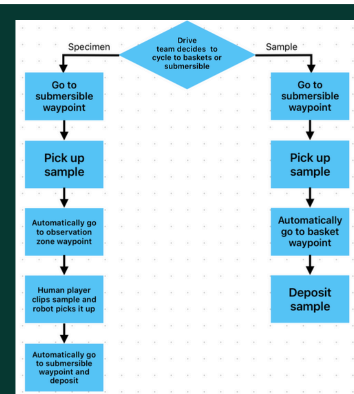
Robot autonomously aligning with specimen during TeleOp



Our specimen cycling path during TeleOp



Our basket cycling path during TeleOp



Waypointing flowchart

LESSONS LEARNED

Problem: Initial misalignment between mechanical design and programming
- Held regular meetings to **improve collaboration** and **align goals**.
- Ensured mechanisms were built with stress testing in mind, **reducing last-minute workarounds** and enabling **smoother feature implementation.**

Problem: A lot of manual code was being written, taking up a lot of time and making it hard to debug
- We **advanced** our programming by exploring **new libraries**, such as FTC Lib and PedroPathing.
- This enhanced **automation**, and **improving** driver controls.
- We **strengthened collaboration** with the mechanical team for better integration.
- Made controlling subsystems much easier.

Problem: Poor time management led to rushed coding, leaving little time for debugging and testing.
- Focused on better **time allocation** to ensure adequate debugging and testing before deadlines.
- Reduced **last-minute emergency fixes** on competition day, decreasing stress and improving reliability.