FTC 16461 INFINITE TURTLES

ENGINEERING PORTFOLIO

TEAM PLAN

Team Intro

We are team #16461, Infinite Turtles, from Matthews, North Carolina. We're a student-led, veteran team who first competed in Skystone (2019-20).

We have **63 years of FIRST experience**, winning **1st place NC Inspire** and Winning Alliance this year, 3rd place NC Inspire last year, and team members have won states (9548) and the Maryland Tech Invitational (18253). **We strive to broaden perspectives on our team, evident in our diversity this year!**

Co-Captains
(Davy & Sid)

Hardware	Software	Business
Davy	Ryan	Sanjita
Sid	Zoaib	Iniya
Devan	Jonathan	Brook
Pavan	Amudhan	

Team Management

Our team is entirely **student-led**, which means that meetings are scheduled and ran by our student leaders. We have **two captains** who oversee the team and agenda, as well as **leads** for each division.

Our coaches are there to manage bank accounts, make sure we get to competitions, and communicate things to parents! This model works well for us because it **builds student leaders** and **develops a sense of responsibility** among our members.

Recruiting and Sustainability

Our team has strong funding support and a consistent workspace at our coach's house, so our main focus to keep our team sustainable is **keeping a strong member base**. This year we recruited 1 new member and had zero graduations, but with some upcoming senior graduations we have plans in place to make sure we stay in function:

- **Yearly May Open Houses:** We host an open house each year that is advertised on social media to help gauge new member interest! This is how **all but two** of our members have been recruited, showing its effectiveness.
- **Outreach in Community:** Increasing FIRST awareness is good for the program, and for our team-by performing outreach locally, we introduce people to FIRST who then might consider our team.

TEAM PLAN

Fundraising and Sponsors

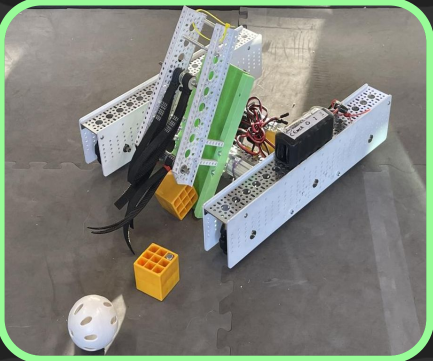
We gain sponsors through our community connections as well as contacting companies ourselves to ask for sponsorships! We have sponsors that support us financially as well as with resources.

Monetary: Google, Microsoft, Collins Aerospace
Discount: SendCutSend, goBILDA, Servo City
Materials: Clickfold Plastics
Software: Mathworks, Simscale, Github, Google

Green highlighted sponsors are continuous, carrying over from last year!

Mentors

Our mentors help build our skills. Experts like **Coach Rick** and **Florent Astie** guide us with their knowledge, but never tell us the answer directly. We typically **recruit** mentors from community platforms and technical connections with companies.



Skill Sustainability - Outreach Bot

With the **high level mechanical work** our team does, it can create an **unstable environment** where basic skills often get neglected in favor of advanced work. Through our outreach bot, we are able to build consistency in learning. We build a second robot to help build these skills, such as **CAD with COTS parts** and **mechanical assembly**. This bot is also used at outreach events to practice presenting skills, another benefit!

Solo Learning: What Are We Proud Of?

Davy – learning FEA and further developing CAD skills with bot structure!
Sid – community interaction and creating resources impacting all of FTC!
Ryan – contributing to the open source FTC programming community.
Pavan – improving CAD skills and documentation.
Sanjita – working with the global FIRST community & learning control theory
Amudhan – learning code and mechanical skills.
Brook – learning post processing techniques, and spreading FIRST!
Zoaib – learning CAD and improving his FTC programming skills!
Iniya – connecting with the FIRST community, learning, and teaching!
Jonathan – learning to code the outreach bot.
Devan – learning to code and enhancing his mechanical understanding.

Preseason Financial Planning

Date	Description	Income	Expense	Balance
4/13/2021	Team Dues	$463.13		$1,722.81
4/13/2021	Microsoft Income	$1,000		$2,185.94
5/17/2021	Offseason DT Plates (SCS)		$67.15	$2,118.79
5/20/2021	Offseason DT Belts (V-Belt Guys)		$26.53	$2,092.26
5/20/2021	Offseason DT Parts (goBILDA)		$356.90	$1,735.36
5/23/2021	Offseason DT Tools (goBILDA)		$49.54	$1,685.82
05/23/2021	Team Registration (FIRST)		$284.37	$1,401.45
05/24/2021	Control Hub (REV)		$294.94	$1,106.51
05/27/2021	Freight Frenzy Field (AndyMark)		$515.56	$590.95
06/01/2021	(Not Gaffers) Freight Frenzy Tape		$81.44	$509.51
06/09/2021	Offseason DT E-Clips (McMaster)		$17.16	$492.35
06/18/2021	Driver Hub (REV)		$225.23	$267.12
07/22/2021	Team Dues	$2,801.25		$3,068.37
TENTATIVE				
	Registration		$350	$2,718.37
	Merch		$450	$2,268.37
	Robot		$1,500	$768.37
	Misc. Parts and Tools		$300	$468.37
	Outreach Bot		$1,000	-$531.63
	Microsoft Income	$3,900		$3,368.37

OUTREACH - STEM TEACHING

Outreach Program Summary

Through our **STEM education programs**, we aimed to reach out to our **local and state communities** to provide education and resources for getting involved in FIRST and the **value of involvement in STEM**.

Impact: 600 Students | Hours: 100

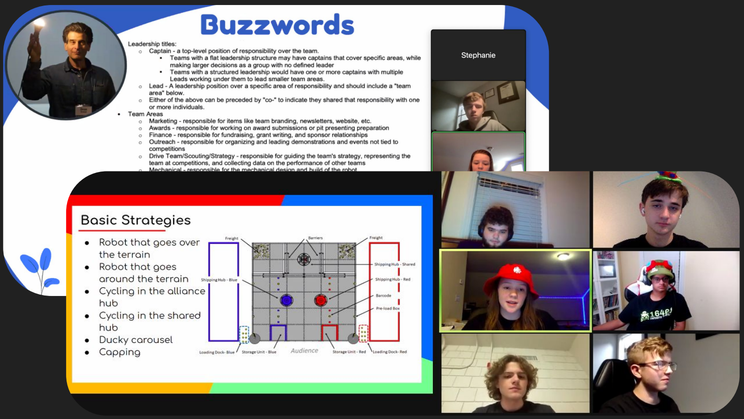
FLL Competition Volunteering
4 Competitions

We make sure to support our home program in NC that raised all of us through FLL! This year we provided **most of our team as volunteers and referees** to **3** different official FLL tournaments (including our region's state champs) and **1** unofficial tournament, helping maintain the FLL community in our area.

Community Demo
Girls in Aviation Day

Over **100** girl scouts and their families came to our booth at an airport event to learn about FIRST! One group was so interested that we **helped them start their own FLL team.**

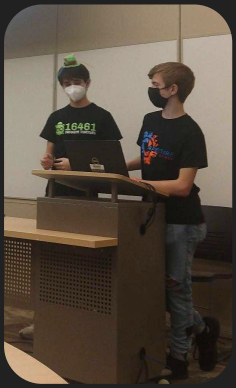
Community Discussions - 3 Events



We worked with other NC teams to come together **to share our knowledge and experience!** We helped host and participated in **3 group discussions:** a post kickoff brainstorming session, a post scrimmage strategy review, and a dean's list clinic to give tips to nominees!

NC FLL & FTC Kickoff - 5 Classes

Our kickoff classes had **60+ FLL** attendees and **100+ FTC** attendees! We taught FLL teams about project development and robot consistency and we taught FTC teams about 3d printing, the design process, and rendering!



OUTREACH - PUBLIC RESOURCES

Outreach Program Summary

Through our Public Resource programs, we are able to contribute to the **permanence of information in FIRST**, providing resources in our **areas of expertise** such as 3D printing, design and team management.

Impact: 160,000+ Views | **Hours:** 300

gm0.org

190k+ Views

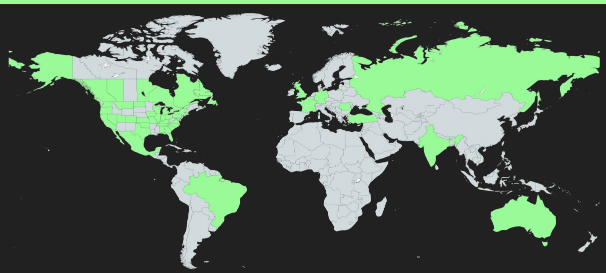
[REDACTED]

Blender4FTC

2k+ Views

A custom Python library we created last year for the open source software Blender to help teams create renders of their robot CAD with a docs site and support. **This year we've kept this software up to date and provided support to all teams.**

- ★ **310 All-Time Downloads**
- ★ **40 Custom Shaders**



COREFTC's Impact

15 Countries | **37/50** US States | **8/13** CAN Territories

FTC Files

800 Students, 3k+ Views

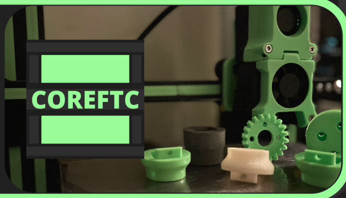
FTC Files is a project to provide open source awards and team structure resources. This year we worked hard to provide additional knowledge on topics such as **limited budget robots, optimization** and **building off-meta**.

We've also worked on the **FTC Files Discord**, which has **800 members** and helps provide a posting ground for engineering documentation. We are responsible for over a quarter of all FTC Files content.

This is a project between us and FTC 14481 (Plainsboro, NJ), also present here at the World Championship.

COREFTC

5k+ Views



COREFTC is a library of information that we created this year to help teams **learn the valuable industry skill of 3d printing**, which also will benefit teams in their own FTC adventures. It provides information on **manufacturing consistency, speed, and strength**. Check it out: www.coreftc.org!

- ★ **15,000 Words of Material**
- ★ **4,000 Views**
- ★ **30 Pages full of tips**
- ★ **11 Countries reached**

OUTREACH - FIRST COMMUNITY

Mentoring

3 teams

We adhere to the FIRST guidelines for **Mentoring** for teams **FTC 5890** from San Antonio, TX, **FTC 18175** from Charlotte, NC, and **FLL 38482** from Ballantyne, NC.

We have mentorship letters from these teams available on request, confirming details of our relationship and specific assistance throughout the season.

FTC Discord

10,000 Students

Our team has **1 admin and 1 moderator** on the **FTC discord server (partnered officially with Discord),** We help make sure that the community remains a **safe and welcoming place** for all members to develop their skill.

- ★ **1,000,000** Messages Since Kickoff
- ★ **10,000** Members
- ★ **2,500 Weekly Visitors**

Direct Assistance

~50 teams

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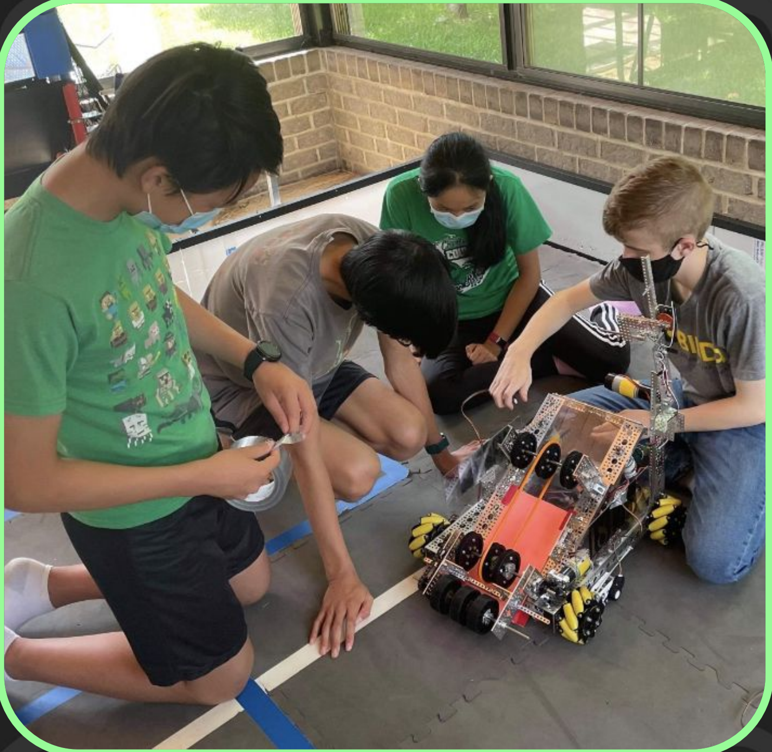

OUTREACH - INDUSTRY

Collins Aerospace

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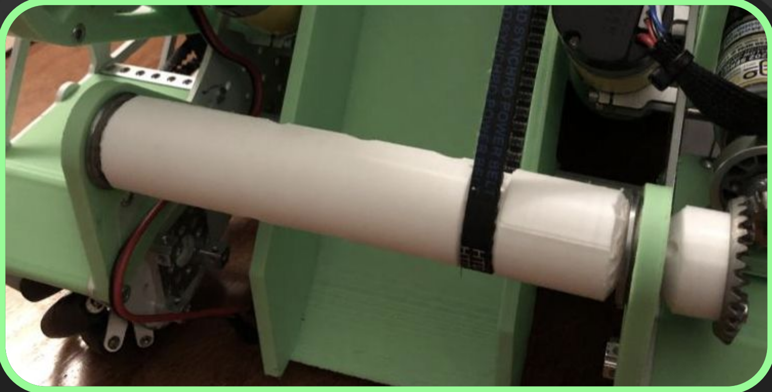


Auris Health

When working with capstone design, we were seeking advice on the usage of magnets. We got in touch with Andrew Torrance, an engineer at Auris Health and a mentor on FRC 254. Mr. Torrance advised us on **minimizing magnet contact distance** and **auto-orienting magnetic fields.** With his advice, we reached a successful end result of that capstone iteration, but later unfortunately had to revise the design for other purposes.

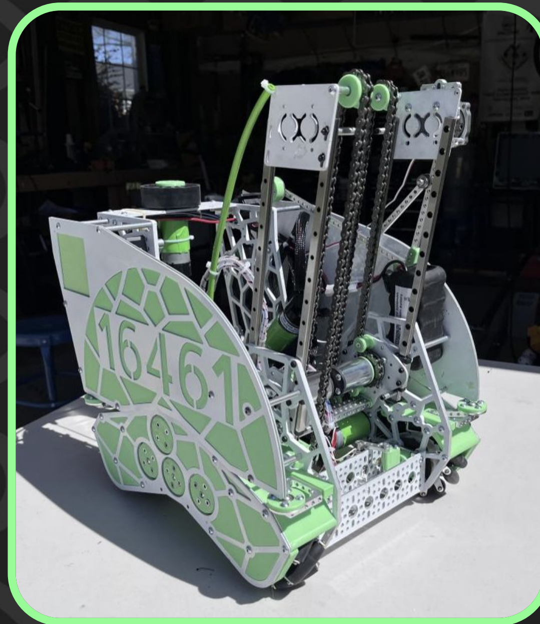
iRobot

A mechanical engineer at iRobot in Boston and alumni of worlds FTC team 5667, Florent Astie has worked with us closely to improve our design skills, as a team mentor. Flo has taught us to focus on **robustness and hardware quality,** guiding us to make our robot the strongest and most consistent it can be. **A specific instance of Flo helping us is him advising us to redesign our intake to take larger hits, which came in handy at our first scrimmage!**

Simscale

[REDACTED]

STRATEGY & DESIGN PROCESS

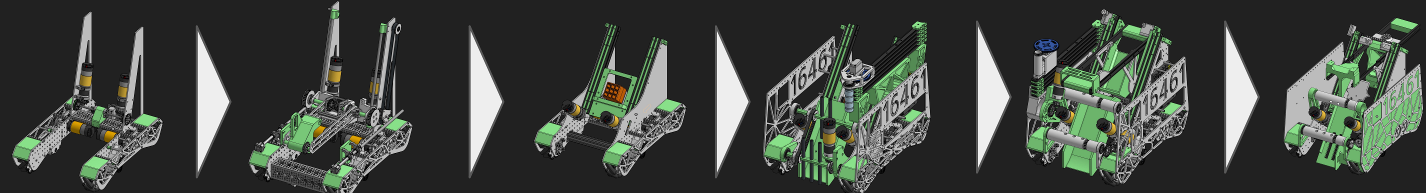


We chose to start the season by **aiming to accomplish every mission on the field** due to our expansive experience. We brainstormed mechanisms that would be able to do so, and succeeded with combinations of **20 Alliance Hub Cycles, 20 Shared Hub Cycles, All Ducks, 2 Capstones, and Parking.** This approach to game strategy this year was a challenge and a learning experience, and carried through all 3 of our team's robots, pictured above (Scrimmage, Region, and Worlds robots left to right)

Design Process - Digital and Agile Philosophy

Our team follows a design process closely that focuses on the design and simulation of parts virtually to ensure proper function before we manufacture and test. Many of our iterations exist **solely in CAD**, which increases our design speed and lowers robot costs. We operate with speed and agility too, **Failing Fast and Often**, which helps us make the best bot we can without lingering on ideas.

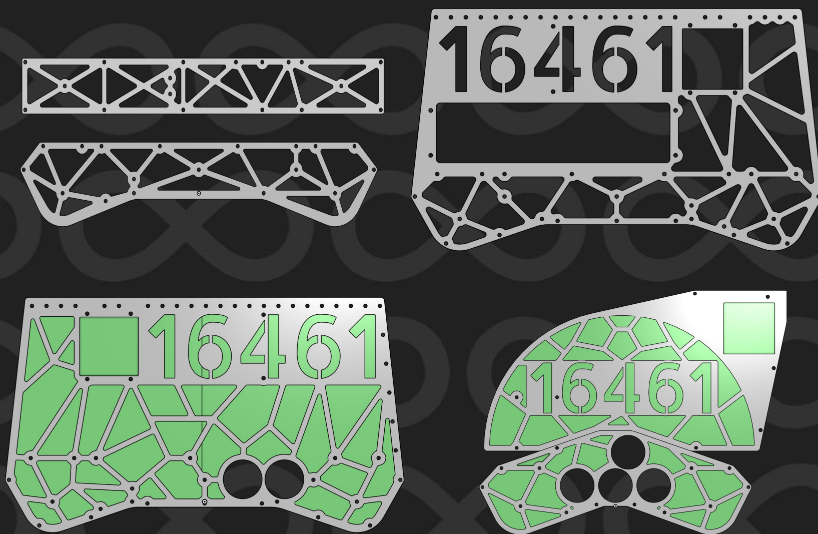
Pre-States Design Evolution

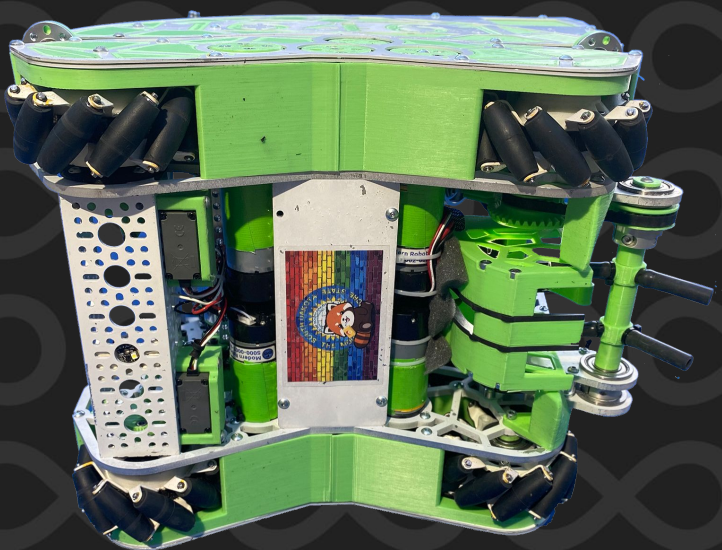


ROBOT CHASSIS

Drivetrain

-7.5ft/s free speed, 6.5ft/s simulated and match speed
-11.5" wide to fit through the gap
-Mecanum and Locking Mecanum
-Fully custom aluminum structure with weight optimization and static analysis
-Side rollers for easy movement along walls





Terrain Handling

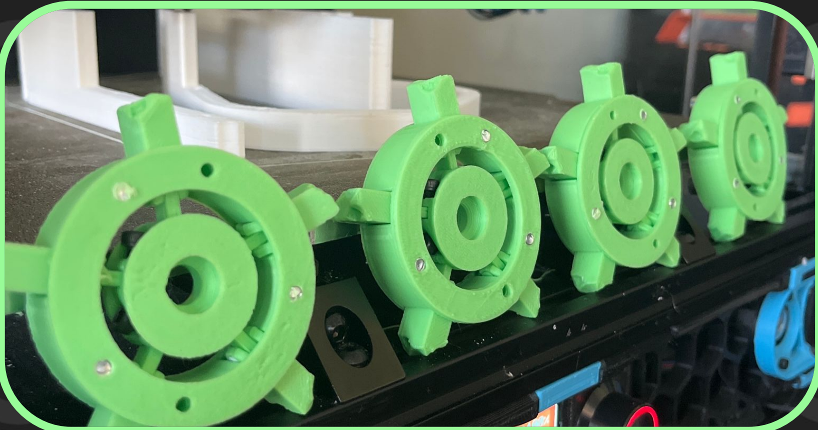
-High clearance and sealed drivetrain base to not catch
-Locking Mecanum for a traction boost
-Full barrier clearance on all mechanisms
-Ratio that balances acceleration and speed for efficient barrier crossing

Lessons Learned

This drivetrain taught us our biggest lesson this year- simulate everything. We wasted many months and lost a lot of points to a very slow ratio, and didn't get around to updating it util our version 3. If we had done this when starting out, we would have performed much better, earlier, so **we've resolved to simulate drivetrain speed profiles at the very start of the season every year from now on.**

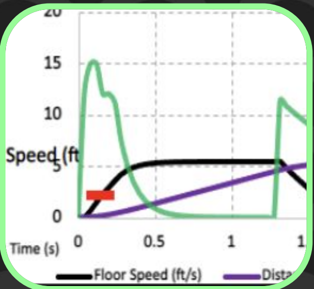
LOCKING MECANUM

We are the **first FTC team** to create a **"Locking Mecanum"**, a modified mecanum wheel that can function as both a traction and holonomic wheel. It does this with **six linkages made with some of the most advanced manufacturing and 3d printing post processing methods in FTC.** The rollers are "locked" in place by this **custom servo driven mechanism** and the wheel becomes an effective traction wheel at our will, giving us the benefits of such!

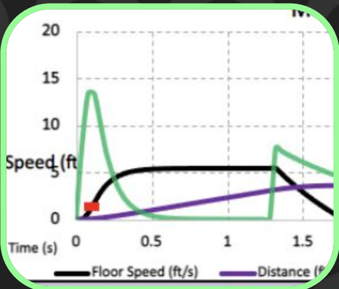


Full Holonomic Capability

1.4x	1.2x
Tractive Force	**Acceleration**

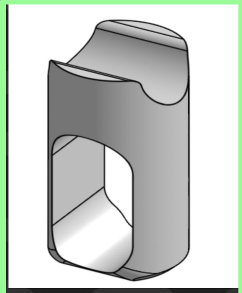


Unlocked Accel Curves (ILITE Simulator)



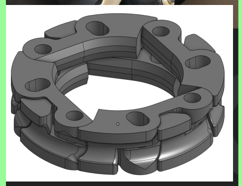
Locked Accel Curves (ILITE Simulator)

Design Process



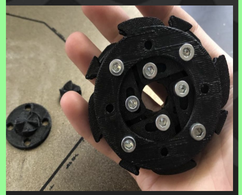
V1 goBILDA
goRAIL lead screw based with a round belt held by pins. **(Too Precise)**

V2 Actobotics
Converted to acto x-rail core with the same breaking mechanism. **(Melted)**



V3 Hemisphere Iris
Iris opener with hemispheres to press into rollers. **(Tough to Actuate)**

V4 Pen Clicker Mech
Pen clicker mechanism to actuate open the iris. **(Too Complex)**



V5 Fine Plunger
This version used a pin with a high angle to actuate. **(Easy to Break)**

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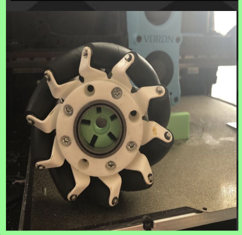

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DEPOSIT SYSTEM

Design Process

V1 Belt Differential Deposit 1
A simple 1 axis belt differential to move/drop elements
(No Reach)

V2 Belt Differential Deposit 2
Added horizontal extension to the differential's capabilities
(Couldn't do Shared Hub)

V3 Belt Differential Deposit 3
Added a servo turret to allow depositing to the side.
(Slower than optimal)

V4 Chain Differential Deposit
Much faster and sturdier deposit with an arm instead of horizontal extension..
(Working)

Our Differential		
	+	-
+	Lift Up	Arm In
-	Arm Out	Lift Down

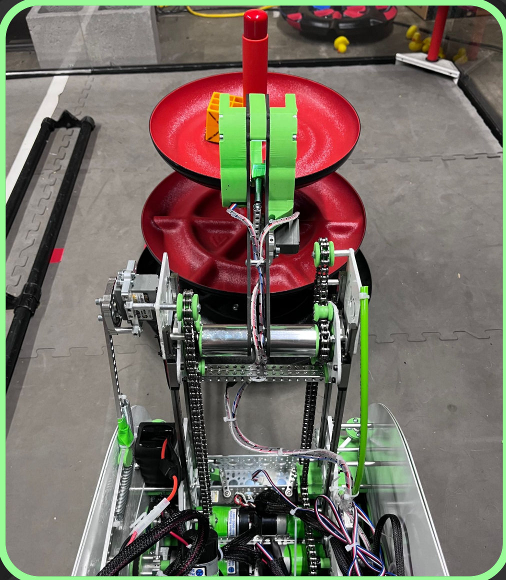
- ★ **Max arm speed: 25ft/s**
- ★ **Mechanically efficient linear rail lift**
- ★ **Stable crossbeam support**

Chain Differential

This year we are using a **chain differential**, a mechanism with similar properties to a differential that uses two inputs to control two outputs with variable power (chart above). Our unique differential controls vertical extension and arm rotation, allowing us to move our lift with speed and precision.

We used **Recalc Simulator** to determine that a 13.7:1 ratio motor was ideal for our lift, giving us ideal acceleration and speed.

We started off this season with a belt differential inspired by FTC team 9881, but eventually swapped to chain for less stretch, easier maintenance, and our own spin on the concept.



INTAKE SYSTEM

“Touch it, Own It”

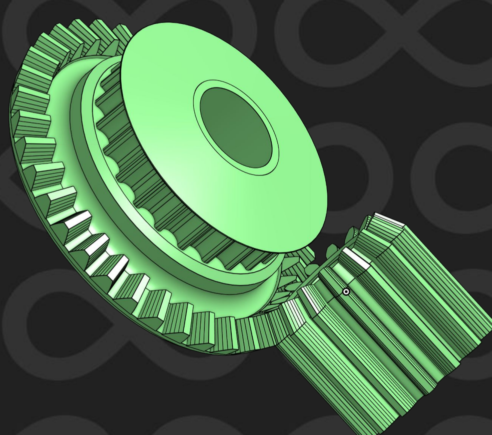
We operate on the FRC principle of **“Touch it, Own it”**. Once an element touches our robot’s intake, we control it fully, even able to **intake while driving the other direction**.c

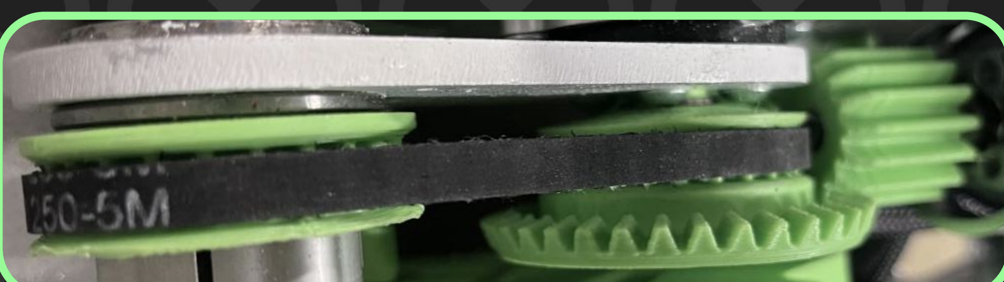
Flipout Intake

By designing a **flipout intake,** primarily intended to avoid disturbing the warehouse, we were able to better package our intake for **stability, strength, and sizing** in our small robot.

Power Transmission

Our **unique multistage power transmission** has 3d printed gears and pulleys connected and compacted as effectively as possible.





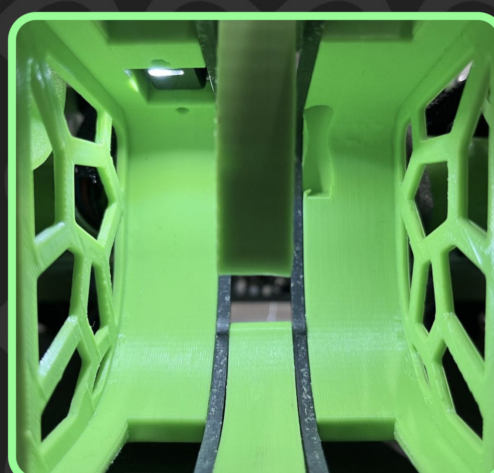
Design Process

V1 Belt Intake
An intake with cut timing belts to grip and propel cubes.
(No grip)

V2 Tubing Intake
A surgical tubing intake with a defined path. **(Often Got Possession Penalties)**

V3 Updated Tubing Intake
Added a linkage gate to only intake one element.
(Unreliable and slow)

V4 Short Tubing Intake
Shortened intake path to have no transfer and added flipout capabilities. **(Working)**



Color Sensor Detection

DUCK MECHANISM HISTORY

VERSION 1 — Continuous Duck

Our first duck mechanism this year was a stab at **task overlap**. We engineered a duck mechanism mounted on an extension to theoretically allow us to cycle while doing carousel. We had it working mechanically, but found out that it was far **too complex** and tough to drive to feasibly run in competition.

Why we decided to move on: Complexity isn't always best!

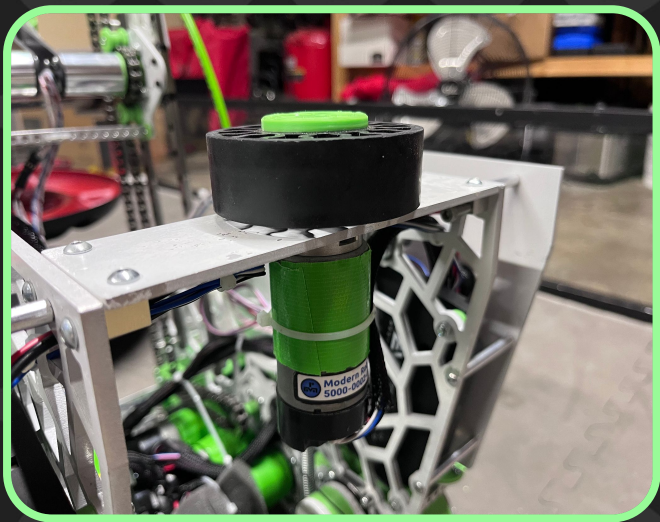
VERSION 2 — A Simple Wheel

Our second duck mechanism this year was a simple wheel. We did calculations to **max out spinning speed** on our motor using our physics experience, but still lost out on some speed once the duck hit the sweeper.

Why we decided to move on: We could optimize on speed a little bit further.

$$\frac{mv^2}{r} = mg\mu \qquad \frac{0.02v^2}{0.15} = 0.02 * 9.8 * 0.5 \qquad v = 0.86\frac{m}{s}$$

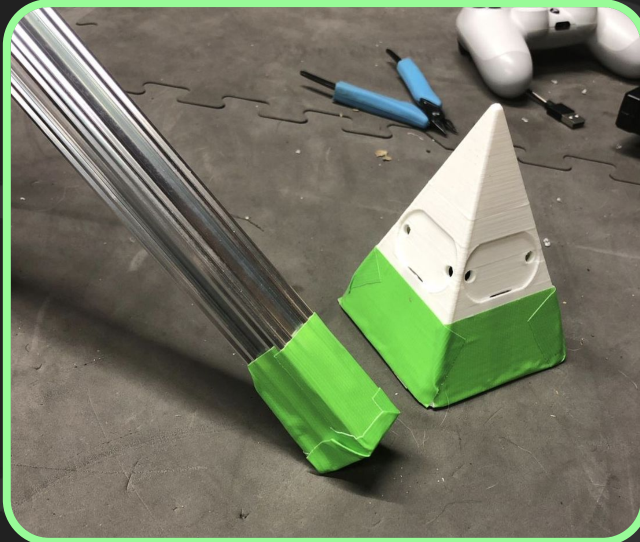
VERSION 3 — The FASTEST wheel



Where's the safety glasses?? We kicked our duck motor up to **6000 rpm** for our worlds bot, sending ducks flying off the sweeper bar. Let's just hope all the carousels are properly constrained though, because otherwise there might be some large frisbees on Davinci! Overall though, this mech has served us well and satisfied our pursuit of an ideal and simple design.

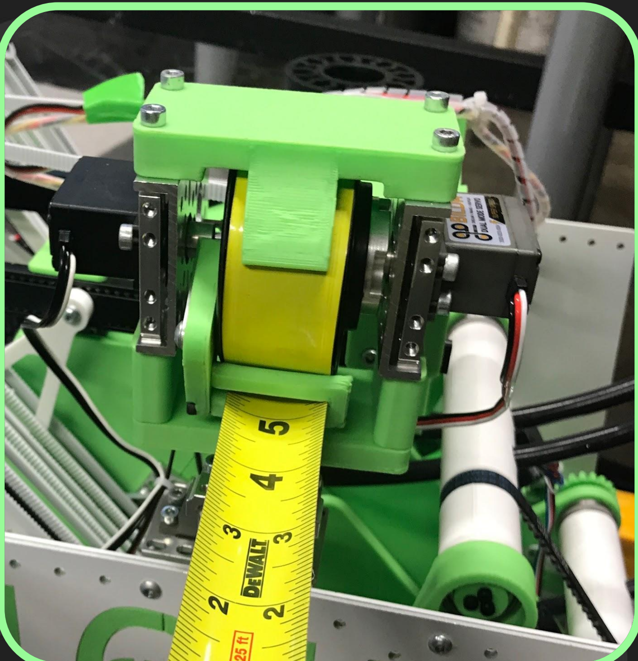
TSE MECHANISM HISTORY

VERSION 1 Auto-Orienting Arm



Our first cap mechanism this year was a **multimagnet arm on 1 axis** that could just barely pick up our cone shaped capstones and place them down. From the first test we recognized that it was a **temporary solution**. For the time being though, features like auto-orienting using multiple magnets were fun to play with!

Why we decided to move on: We saw the idea of tape measure cap executed by other teams!



VERSION 2 Tape Measure

Our second cap mechanism this year was a 3 axis turret that was able to pick up and score a TSE from 9 feet away, allowing **task overlap** with carousel. It utilized a unpackaged tape measure with custom casing.

Why we decided to move on: It performed inconsistently at our state champs, losing us points.

3.00pt/s → 4.66pt/s

With task overlap

VERSION 3 2-Stage Sprung Arm

Our final capping mechanism this year is a **2 stage sprung arm** with a bearing supported magnet on the endpiece. This allows us to pick up a capstone and have it remain level with the ground, and also retract our arm back into the robot without extending past the size limit. Simplicity was also a focus here, not wanting a difficult to repair mechanism for the long event that worlds is.

PROGRAMMING - DEVELOPMENT

Developer Tooling

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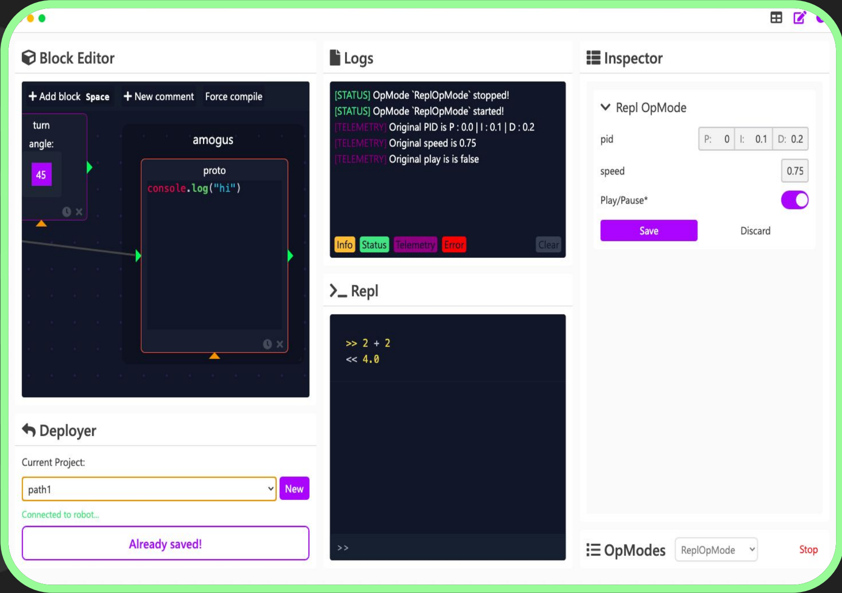
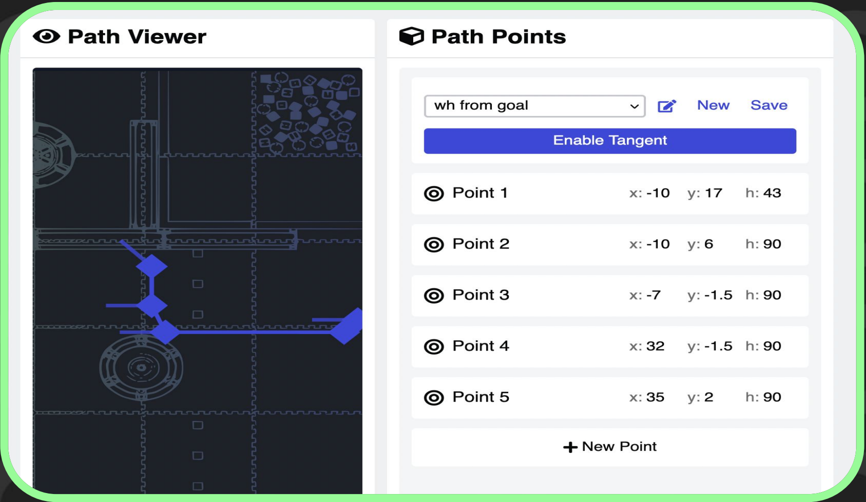




Live Updating

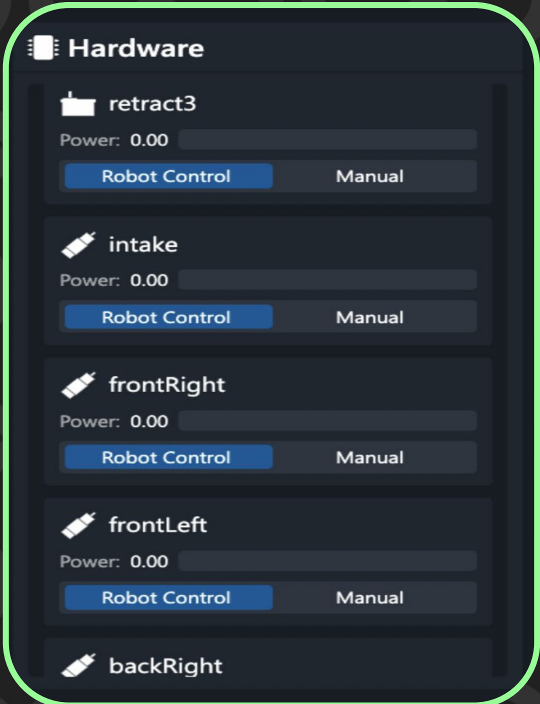
- ★ Typically, it takes **2+ minutes** to build and upload a single code change to an FTC robot.
- ★ Our **custom dashboard** allows us to **live update** variables, paths, and more on the bot.
- ★ This allows us to prototype values in realtime, **without having to wait minutes** for each change.

Languages

FTC normally starts and stops at **Java**– but we decided to see what other languages offer for us.

- ★ **All** of our robot code is in **Kotlin**, a common java alternative with syntax improvements.
- ★ Our custom web dashboard is coded in **Svelte**, **Javascript**, **CSS**, **Typescript**, and **HTML**, providing all the features we needed (with a lot of learning mixed in).

We enjoyed playing with other coding languages for FTC this year and encourage others to do the same!



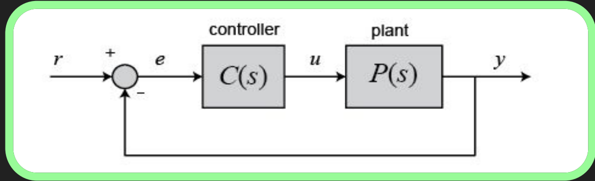
PROGRAMMING - GENERAL

PID Controllers

We use PID-F to **accurately follow paths**, define our **motion on lift, intake, and drivetrain**, and dynamically control the velocity of our bot, maximizing the efficiency and speed of each action. We understand the concepts of PID at a core level, with 13+ semesters of college math on our team ranging from Calculus 1 all the way to Multivariable Calculus and Differential Equations.

PID In Equation Form

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



Our control theory implementation of PID

Machine Vision

We use machine vision to identify our capstone in auto, using special **April Tags** to make our vision reliable. Thanks to an OpenFTC JNI integration for C++ library, we can use the AprilTags in our code with a **custom OpenCV pipeline**. We added a Kotlin wrapper to work in our codebase, allowing us to work with it more easily and increase efficiency. **April Tags can be detected in any intensity and color of light.**

Color Sensor Optimization

Instead of the default SDK method of calling a value from our color sensor for each RGB value, we pull **raw hexadecimal data from i2c**, cutting hardware calls down to one for performance. Using this we also found that numbers were more stable, decreasing sensor anomalies. Pictured right are some of our hand calculations solving a system of equations to determine the optimal freight detection values.