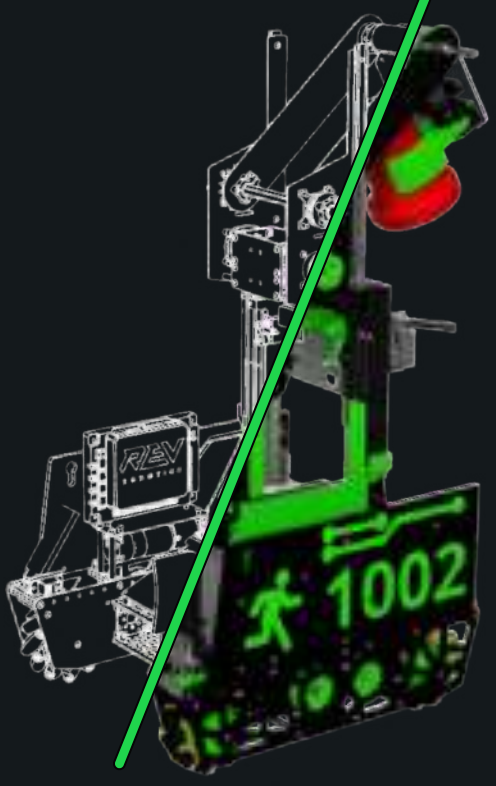
1002 CIRCUITRUNNERS

SURGE

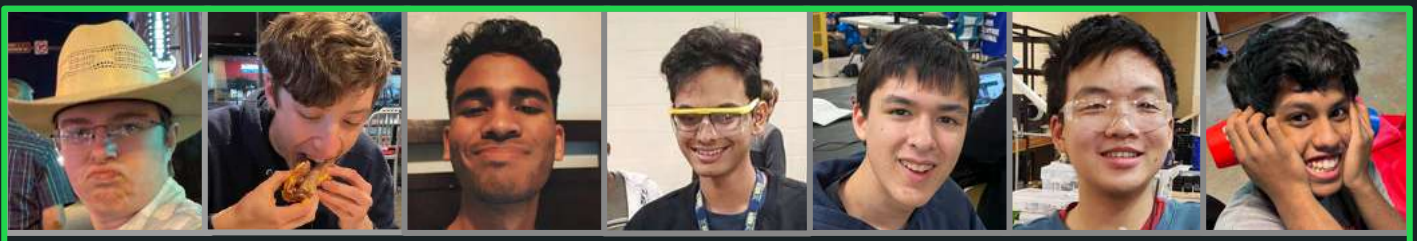


ENGINEERING PORTFOLIO

2022 - 23

WHEELER CircuitRunners

We are FTC 1002 CircuitRunners Surge!



Aidan	Ryan	Rokib	Aarush	Jason	Richard	Samarth
4th Season	4th Season	3rd Season	2nd Season	2nd Season	2nd Season	2nd Season

Kavin	Eliza	Abby	Sohini	Ethan	Dillan	Madelyn
2nd Season	1st Season	1st Season	1st Season	1st Season	1st Season	1st Season

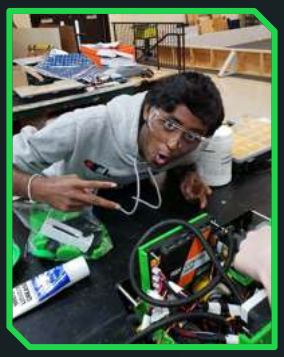
Mentors

Cameron Huggins

Davy Hallihan

Mars Berwanger

August Longhurst



Nelitha Kulasiri

Acquiring Mentors

This season, we have made an effort to ensure that knowledge will be preserved in future seasons by finding new mentors for our team!

- ➢ CircuitRunners alumni networks
- ➢ Existing mentor connections
- ➢ Local technical firms and businesses

How Our Mentors Help Us

- ➢ Presentation practice for our judging interviews
- ➢ Build and design skills when trying to manufacture challenging parts or assemblies
- ➢ Shop training for newer members to properly use all of our shop tools.
- ➢ Hosting events such as scrimmages and planning event logistics

➢ New this season: Cameron and Mr. Berwanger are helping us learn CNC Machining to move part production fully in-house.

Team Plan

Season Goal

➢ Participate in as many robot demonstrations monthly to present STEM and FIRST to our local community.
➢ Retain 100% of new rookie members.
➢ Invite 3+ Professionals in STEM careers to talk about their lives and experiences.
➢ Expand our impact globally by mentoring 2+ FIRST Global Challenge teams.
➢ Establish a continuing sponsor base for commonly used goods.

Marketing

Finding diverse, creative ways to market our team, STEM, and FIRST is a core part of our activities this season. To do this, we have focused our efforts on three main categories: locally, nationally, and globally.

Locally

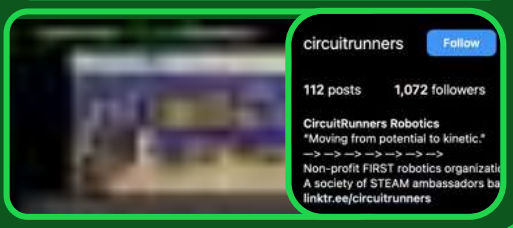
➢ Set up materials in our high school showcasing our activities.
➢ Run robot demonstrations in many local schools, including ours (See Outreach Overview)

Nationally

➢ Congresswoman Lucy McBath toured our shop and discussed challenges facing STEM programs in our state (more on pg.7)

Globally

➢ Set up a new official club website, Instagram, Facebook, and more to showcase our STEM contributions to our community.



Fundraising

➢ Money was raised with our member dues
➢ To keep CircuitRunners funded, we pursued donations from four new companies.
➢ We apply for many grants, and have received funds from DOW Chemical, PTC, Costco, and more.
➢ We maintain constant monthly contact with our new sponsors and send updates of our competition progress, and were even featured in a blog article on Coex 3D!

Outreach

➢ Reached 10,000+ individuals through our social media and newsletters
➢ Reached 2,000+ individuals through various outreach initiatives to promote interest in STEM & FIRST and many more through Representative Lucy McBath
➢ Reached 100,000+ individuals by name through Representative McBath's newsletter.

Thank You, Sponsors!

Member Development

➢ With 7 new rookie members on our team this season, we needed an efficient process to fully integrate them into team roles.
➢ We designed a 3-stage development program to teach rookies the necessary skills to successfully contribute to our team.

Stage 1: Basic Skills

Goal: Teach basic skills needed for all areas of FTC to new members.

Steps Taken:
➢ Members were given the task of building a pre-designed robot using instructions.
➢ Familiarized with tools and common parts.
➢ Collaborated to assemble different sections of the design.
➢ Introduced to basic FTC programming concepts like motors and servos.

Stage 2: Application of Skills

Goal: Have rookies transition from their basic skills to more specialized roles on the team in design, programming, and outreach/marketing

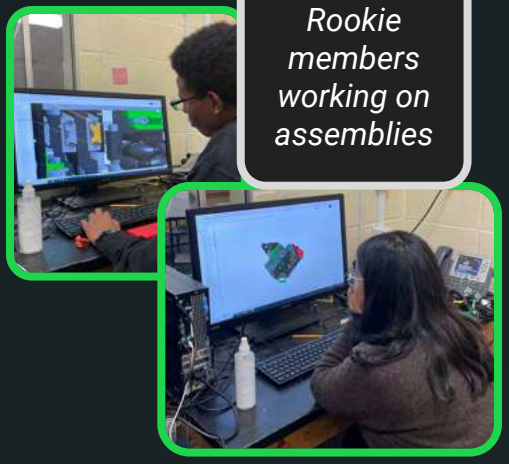
Steps Taken:
➢ Members attended and helped to run robot demonstrations.
➢ Members programmed their first Tele-Op and Autonomous programs under supervision from senior members of the team.
➢ Designed small mechanisms and parts in CAD.
➢ Assisted in communicating to one of our first STEM Speakers.

Rookies working on pre-season robot

Working on the robot at the first league meet

Stage 3: Full Integration

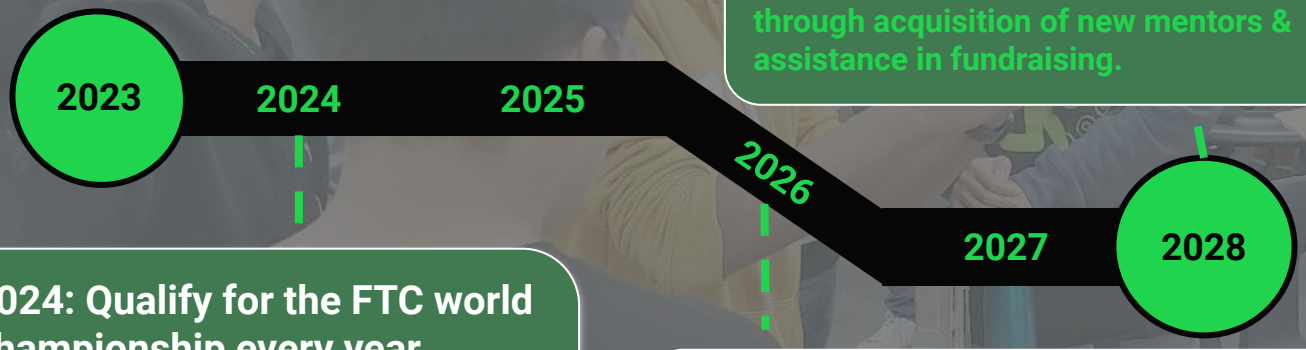
Goal: New members work on more expansive tasks with less supervision, and begin to become more established in the team.
Steps Taken:
➢ New members programmed sections of the autonomous routes used at competitions.
➢ Individually designed numerous components and mechanisms for the robot.
➢ Members helped find and coordinate demonstrations and other outreach activities.



Rookie members working on assemblies

Future Goals & Sustainability

"The Wheeler High School CircuitRunners seeks to instill the values of engineering and business to the surrounding community and across the world. By providing the foundation for students to engage themselves in STEM and leadership, our organization will inspire and create the future leaders that are necessary for advancing society." - CircuitRunners Mission Statement



2024: Qualify for the FTC world championship every year
- Qualifying for worlds every year requires a flow of knowledge from veteran to rookie.
- More formal member development setup

2026: Eliminate team dues
- Additional sponsors will allow us to make member dues free.
- New marketing campaigns to raise money

2028: Help a team advance to worlds
- Invest more into teams that we mentor through acquisition of new mentors & assistance in fundraising.

ANNUAL GOALS

Branch out to more potential sponsors, and establish consistent sponsors.
- Forge a stronger bond with our local community by helping areas in need.
- Search for more mentors to help accomplish our goals.
- In effort to make team dues free, our club has introduced new marketing campaigns to raise money.
- Our team plans to establish a rigid member development plan all throughout the freshman year to ensure our team will have trained and experienced members that are able to qualify for worlds.

SUSTAINABILITY

- Work to recruit new members into the club by:
- Presenting at various events where clubs introduce themselves to prospective students to foster interest.
- Creating videos to showcase robotics for events like Open House and Prospective Student Night.
- Holding informational nights to give info about our organization.
- Working with feeder schools such as helping Sedalia Park Elementary School's FLL team.
- Conducting demonstrations at FLL Events to inspire students to pursue FIRST robotics in high school.
- Keeping member dues as low as possible, so robotics is more accessible.
- Increasing the diversity of our members.
- Conducting outreach to important legislative figures (Congresswoman McBath)
- Member development allows experience to be transferred to rookies from veterans, allowing the club to thrive for years to come.

Outreach Overview

Reached Over 2,000 People!

+10,000 Impacted through Social Media & Newsletters

Mentoring

- **Special Education STEM** — 30 People Reached
- **Mentoring FIRST Global Challenge** — 3 FGC Teams Reached
- **Sedalia Park FLL** — 10 People Reached
- **Mabry Chargers FLL** — 25 People Reached

Event Hosting

- **FLL Super-Regional** — 24 FLL Teams Reached
- **FLL Regional** — 200 People Reached
- **FTC Scrimmage** — 4 FTC Teams Reached
- **FTC Marietta League Meets** — 16 FTC Teams Reached

Robot Demos

- **Varner Elementary** — 300 People Reached
- **Wheeler Magnet Open House** — 350 People Reached
- **Sope Creek Elementary** — 300 People Reached
- **Addison Elementary** — 300 People Reached

Speaker Series

- **KSU Mechatronics** — 20 People Reached
- **COEX 3D** — 20 People Reached
- **GA Tech. Modularity** — 20 People Reached
- **US Rep. Lucy McBath** — Newsletter impacted thousands

Ask Us About Our Outreach At Our Pit!

Working With Special Education Students

➢ Introduced STEM concepts to our school's special education students

➢ Worked through weekly activities and lessons since they don't get the opportunity to learn about STEM.

➢ Let the Special Education students experiment with different boat designs in a challenge to design a tinfoil boat to hold as many coins as possible.

Assisting the Sedalia Park Elementary FLL Team

➢ Helped the Sedalia Park Elementary FLL Team design parts to help them complete missions.

STEM Speaker Series

GOALS

➢ Bring in STEM Professionals from different careers to show our members how STEM is used in the real world.
➢ We currently host one speaker series per month and plan to expand the breadth and depth of our speaker series.

Georgia Tech Modular Design Seminar

Speaker: Jeff Rosen, Manager of K-12 Education @ Georgia Tech

➢ Came to our shop and presented about modularity.
➢ Gave advice about incorporating modular designs into our robots in order to maximize efficiency when iterating new devices and increasing ease of maintenance (see page 14).

Explained the importance of modularity with robot designs, and gave advice on how to make parts interchangeable and repairable.

One of the several engineering projects Leo has made over his career as an engineer

Verdant Robotics

Speaker: Leo Chen, FRC Alumni & Engineer

➢ Spoke about his adventures in robotics, from FRC to designing and launching balloons, to developing innovative farming technology.
➢ Taught members of the importance of the engineering design process and the importance of engineering to society.

KSU Mechatronics

Speakers: Dr. Tanveer, Dr. Voicu, and FTC Alumni KSU students.

➢ Presented the KSU mechatronics program.
➢ Showed off robots made by undergraduate students at KSU.

Showed new members the applications of robotics in their futures early on in the season.

Members check out the KSU Mechatronics robots.

Gave advice on 3D printed part design for our robot parts

Coex 3D Filament

Speaker: Todd Louthain
Owner of Coex 3D

➢ Talked about FIRST and design principles in our work.
➢ Advised us on 3D printing part design and quality control.

Robot Demonstrations

October 6, 2022
Varner Elementary

Displaying FTC robots to potential members of CircuitRunners!

October 22, 2022
Sope Creek Elementary

March 9, 2023
Kemp Elementary

Demonstrating our robot to future Wheeler Magnet students to spark an interest in robotics and FIRST!

October 20, 2022
Magnet Open House

Showing Elementary students the mechanics of driving a robot!

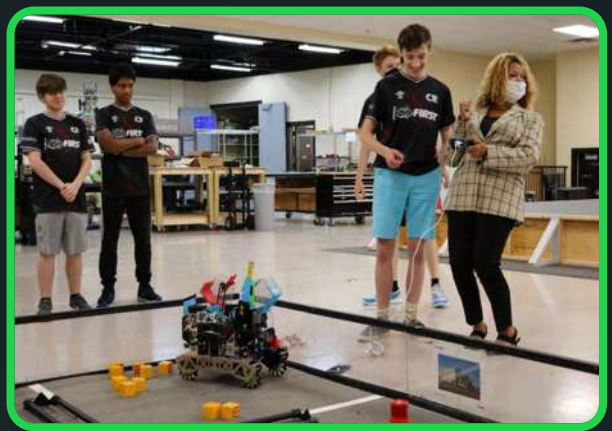
October 22, 2022
Sope Creek Elementary

March 29, 2023
Sedalia Park Elementary

Spoke to potential robotics students about FIRST and FTC!

Welcoming Congresswoman Lucy McBath

➢ **Congresswoman Lucy McBath** visited our shop at the beginning of the season.
➢ She was shown a presentation of how **STEM funding is important in our community.**
➢ Drove our robots and shown around our shop.
Helped reach thousands of her constituents by putting info of FIRST in her newsletter



Partnering with Clubs and Organizations

Partnered with **Girls Who Code**, **Society of Women Engineers**, and **Gender Sexuality Alliance** to increase diversity and promote interest in STEM & FTC through the inclusion of multiple different demographics.

Hosting League Meets and Scrimmages

Design Process

Using the Engineering Design Process

➢ Throughout our season, we used the **5 step engineering design process** to produce the best possible end product.
➢ We never stop trying to **iterate on & improve** our existing designs or conceptualize new ones.

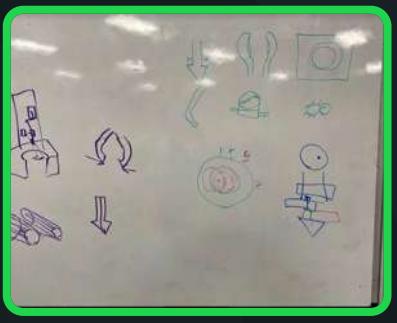
Team discussing new game

1. Define the Problem

➢ **Identify** the problem to be addressed
➢ Gather info and data on the problem to create **constraints**, **goals**, and **objectives**.

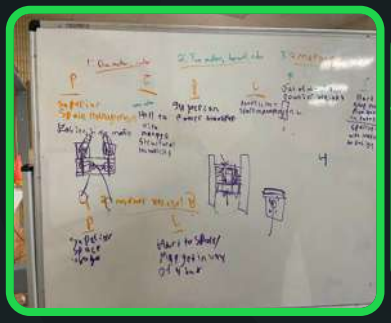
2. Brainstorm Solutions

➢ Group brainstorming introduces ideas from **each person** to the table to maximize possibilities
➢ Sketch and research existing solutions to identify potential problems.



Sketching mechanisms to interact with game elements

Selecting final drive base by identifying pros and cons

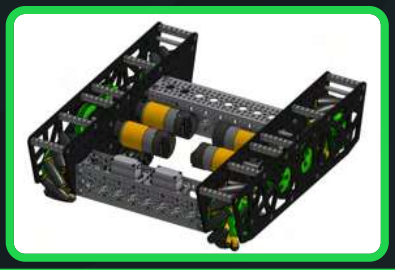


3. Choose the Best Plan

➢ Take ideas from brainstorming and make mockups and **prototypes** to see if they meet the original design constraints.
➢ Choose the design with the most pros and least cons.

4. Implement a Design

➢ Finalize the design and start **modeling** it in CAD.
➢ Create steps to follow in order to **assemble** design.



Utilizing CAD software to implement our ideas

Testing developed mechanisms to gather data for potential upgrades

5. Learn and Improve

➢ The robot is **tested** and evaluated for effectiveness and any improvements are made.
We share our solutions and receive **feedback** from others.
➢ The design process is iterative and is **repeated** multiple times until the design meets the constraints.

REPEAT

Mentoring FIRST Global Teams

FIRST Global Mentoring

➢ FIRST Global is an international robotics competition that features teams from nations around the world to compete in an international competition each year.
➢ We wanted to expand our global reach by offering to provide mentoring and assistance to various FGC teams.
➢ Distributed an intake form for teams and communicated to set up meeting teams.


CircuitRunners First Global Team Intake

ryan.driemeyer@circuitrunners.com (not shared)
Switch account

* Required

What country is your team representing? *

Your answer

What would your team like mentorship for? (check all that apply) *

- [ ] Design
- [ ] Programming
- [ ] Build/Mechanical

Team Turkmenistan

➢ Started robot late, discussed design plans and design schedule to be done in time for competition.
➢ Ryan met every Monday at 12 pm - 1 pm for 4 weeks leading up to the competition.
➢ Provided examples of engineering portfolios and talked about judging strategies.
➢ Ranked 7th in world at FGC 2022 in Geneva!

Ryan talking about intake and transfer designs

Team Tunisia

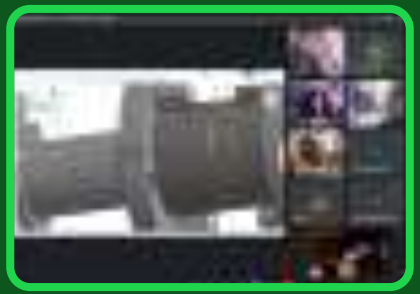
➢ Met over google meets 2 times, and continued to communicate over Discord.
➢ Showed examples of linear extension rigging.
➢ Helped to optimize their motor gear ratio of the climbing mechanism and shooter.
➢ Advised on game strategy and general tactics.

Meeting with the team to talk about awards and robot design strategy

Team Malaysia

➢ Showed how single-motor lift rigging worked.
➢ Met at 6 pm on every Saturday day via Google Meets.
➢ Kept constant communication over WhatsApp.
➢ Advised on intake materials and spool design using the REV kit of parts.

Showing a CAD example of a lfit spool with REV parts

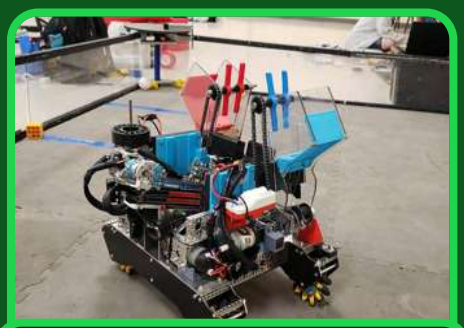


Meet OFFSET

Robot Overview

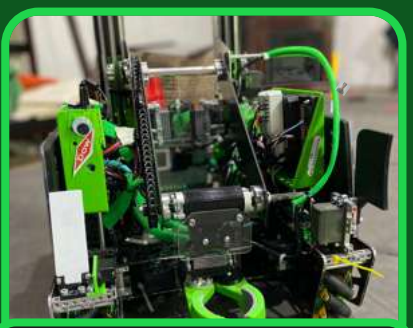
- Passthrough design significantly reduces cycle times allowing us to score more cones.
- Rear two wheels are locking mecanum wheels allowing an increase in traction and acceleration.
- Side clamping claw gives a firm grip on cone with easy alignment.
- Claw can pivot 40 degrees to drop cone at an angle and account for pole misalignment.
- Custom parallel-plate drive base with a width of 14” and a length of 14.5”.
- 6-stage lift gives 35 inches of vertical extension.
- 220mm long virtual 4-bar

Robot Iterations



Cheese Grater →

Misinput →



Offset

Freight Frenzy

Strategy

- Autonomous: 1 cone on High and 5 on Mid, 70 points
- Tele-Op: Set up a circuit early game and defend it.
- Get as much pole possession late game.
- Endgame: Place Beacon and continue to defend circuit, parking at the end of the match

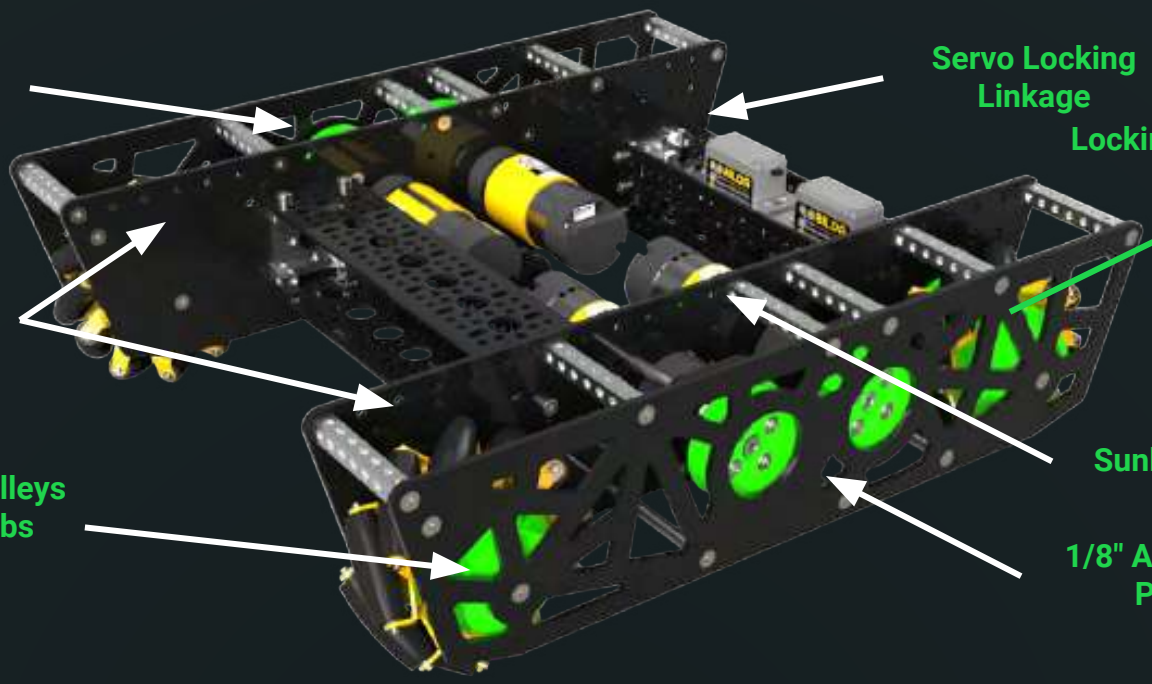
Pros:
- Designed to be simplistic and built quickly
- Small and lightweight, allows for fast cycle times.

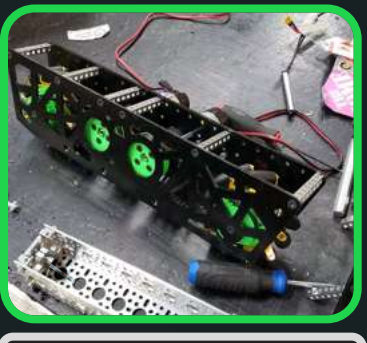
Cons:
- Full turn required for scoring
- Weak claw grip due to lack of contact area with cone
- Single slide set was unstable
- Side plates flexed excessively

Improvements:
- Passthrough design to cycle cones faster and minimize turning
- Improved locking mecanum design
- Uses two sets of slides to increase lift stability
- Switched to thicker ⅛” side plates to reduce flex
- Claw has more contact area with cones

Powerplay

Drive Base





Drive base construction

Highlights

- Rear wheels are both **locking mecanums (see pg.12)** for an increase in traction and acceleration when needed.
- Maximum **theoretical velocity of 6.18 ft/s.**
- 3D Printed custom mecanum wheel hubs provide a **16:1 gear reduction.**
- Total **width of only 14”** and **length of 14.5”** allows for easy maneuvering around the field.
- CNC-ed 1/8“ Aluminum side plates for rigidity.
- **Come see our wheel hub iterations in our pit!**

Total Weight (lbs)	Weight on Driven Wheels		Wheel Dia. (in)
27	100%		3.7795
Drivetrain Free-Speed	Drivetrain Adjusted Speed		"Pushing" Current Draw per Motor
6.18 ft/s	5.26 ft/s		5.09 Amps
16.00 : 1	<-- Overall Gear Ratio		

Total Weight (lbs)	27
Speed Loss Constant	85%
Drivetrain Effeciency	90%
Wheel Diameter (in)	3.779527559
Wheel Coefficient	0.85
Drivetrain Free-Speed	6.08 ft/s
Drivetrain Adjusted Speed	5.17 ft/s
"Pushing" Current Draw per Motor	5.09 Amps

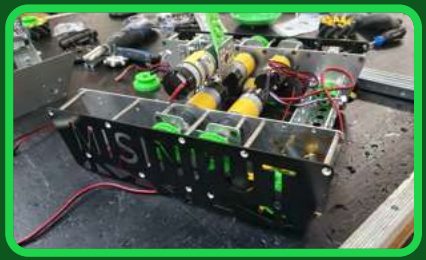
Calculating the most power efficient drivebase gear ratio

Iteration 1: 6-Wheel Drive

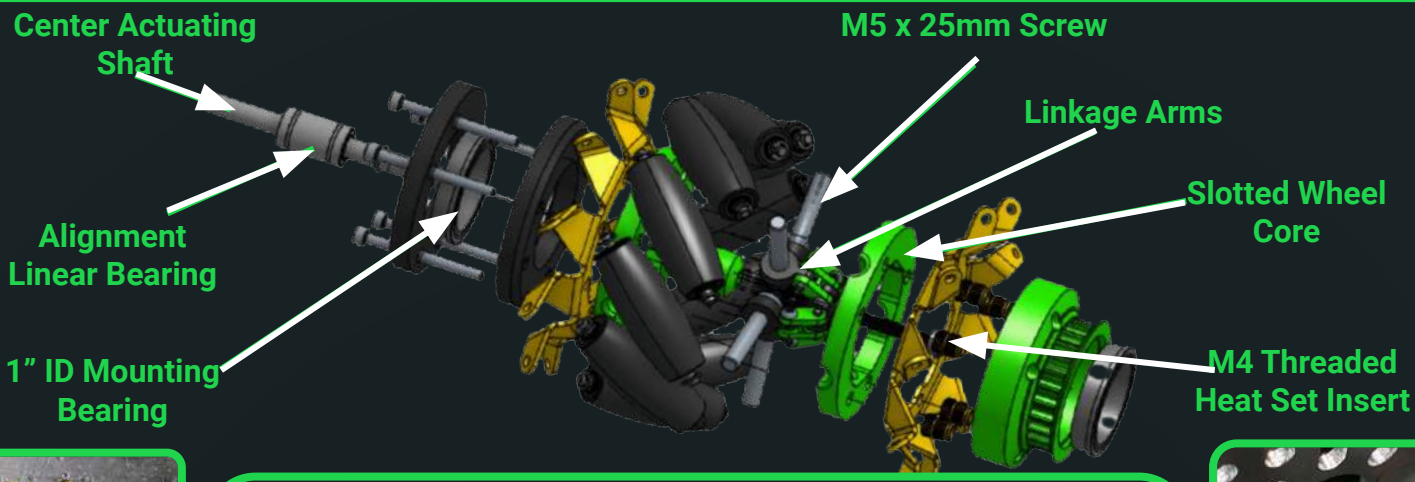
Advantages:	Disadvantages:
High Pushing power, high acceleration	Large footprint Not holonomic

Iteration 2: “Misinput” DT

Advantages:	Disadvantages:
Fast and lightweight	Thin plates led to flexing, few mounting holes



Locking Mecanum (LMEC)



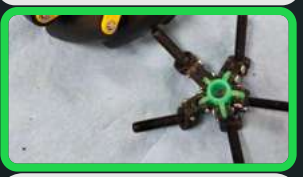
Fully assembled locking mecanum wheel

Servo linkage

Highlights

➢ We are the **only FTC team** to utilize locking mecanum wheels this year.
➢ Designed over **6 months** with **4 iterations** and developed with **3+ kilograms** of 3D printer filament.
➢ A set of **5 linkages** actuates with a servo to push screw threads between the mecanum wheel rollers, **locking them in place.**
➢ By removing roller slippage, the wheel has a measured **1.4x traction increase** corresponding to a **1.2x acceleration increase.**
➢ **Instant** actuation provides option between optimizing wheel for either **traction** or **maneuverability** during teleop.
➢ Allows for **faster** movements along extensive paths and **increases** defense opportunities.
➢ **Come see a working model of the locking mecanum wheel in our pit!**

Linear bearing to align servo linkage



Fully assembled linkage arms and screws

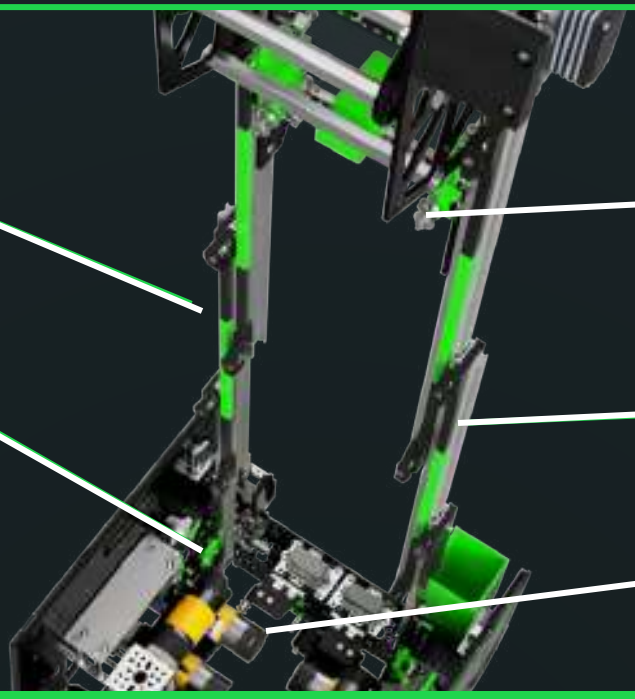
Iteration 1: Horizontal Linkage

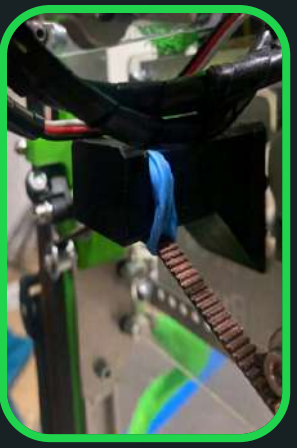
Advantages:	Disadvantages:
Ideal linkage geometry made actuation easy.	Arms lacked enough friction to lock the rollers.

Iteration 2: Screw Spur Brake

Advantages:	Disadvantages:
Fully locked all the rollers.	Center shaft misalignment unevenly extended the linkages.

Belt-Driven Lift

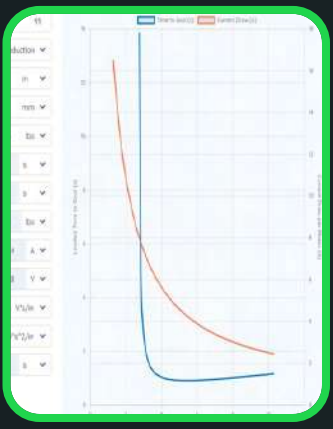




Tensioning the continuous belt

Highlights

- Vertical linear extension with **6 stages** of 400mm drawer slides rising **35 inches.**
- Continuous rigging with 7.6 ft. of **6mm GT2 belt** allows for extremely precise lift movement.
- Powered by two **5.2:1 motors with 60t pulleys,** calculated and optimized for a full extension time of only **0.6 seconds.**
- Unique tensioning design tightens the return belt as it passes across the top of the lift.
- Custom designed slide inserts to hold larger belt idler bearings.
- **Come see the belted rigging up close in our pits!**



Calculating the ideal lift motor gear ratio

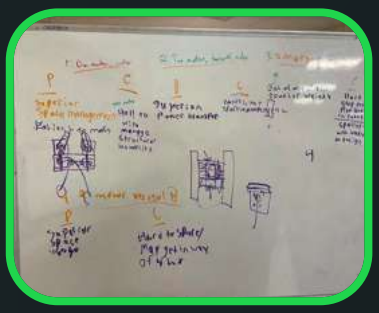
Iteration 1: Single Slide Set

Advantages:	Disadvantages:
Simple to use and program, simplistic continuous rigging with string	Poorly supported, causing leaning when fully extended

Iteration 2: Supported Single Slide

Advantages:	Disadvantages:
Aluminum support plates transferred load better and reduced slide bending	Pole variability made cone alignment tricky.

Passthrough Deposit



Drawings of different passthrough designs

Highlights

- Passthrough scoring design eliminates the need for turning to score.
- Chain power transmission to reduce shock loads on virtual 4-bar servos.
- Servo linkage can pivot gripper 40 degrees outwards to better align cones.
- Modular side-clamping gripper firmly holds cones
- Virtual 4-bar keeps gripper mechanism parallel to the ground and adds extra 8.6 inches of extra extension with carbon fiber plates.
- Full iterations can be found in our pits. Feel free to stop by!

Angled cone dropping helps to align the pole

Finger Gripper

Too little surface area on claw tip

Spike Gripper

Required linear motion to grip cone

Top-Down Gripper V.1

Hard for cone to enter the gripper

Top-Down Gripper V.2

Allowed a lot of play for the cone

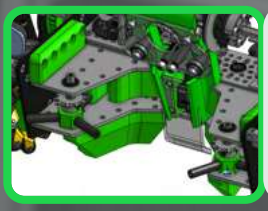
Sprung Intake V.1

Belts often ran off flanges

Sprung Intake V.2

Cone would hit rollers when raised out of intake

Static Intake



Conflicted with horizontal gripper

Gear V4B

Gears experienced too much friction

Chain V4B

Cone would not fit between V4B

One-sided Chain V4B (Poly)

Polycarbonate was too wobbly

Software

April Tags

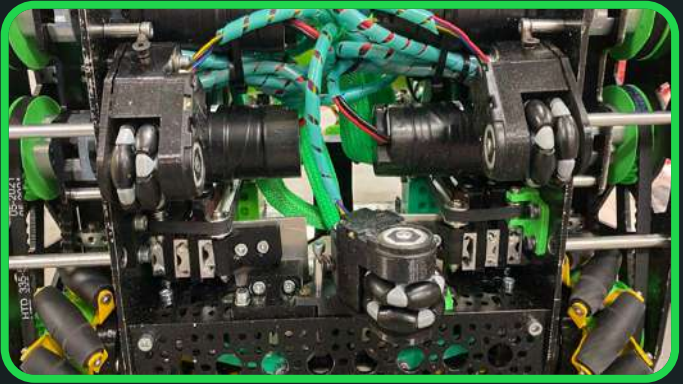
Problem: Our auto needs to consistently detect the correct parking position.
Solution: We used an **April Tag vision target** on our sleeve, a **QR code-like target that is easily detectable by computer vision.**
➤ Using a plugin with the EasyOpenCV library, we obtain the tag's unique ID.
➤ Parking zone is determined by comparing the ID value.

Dead Wheel Odometry

Problem: Our auto needs a very reliable localization system to drive consistently.

1st Solution: Use the **drive motor encoders and the internal IMU gyro sensor** to track the robot's position on the field, but **wheel slippage caused drift over time.**

2nd Solution: Use **3 dead wheel odometry pods** with external encoders to track changes in **position and heading.**
➤ Very little drift over time, tensioned to keep contact with the ground.

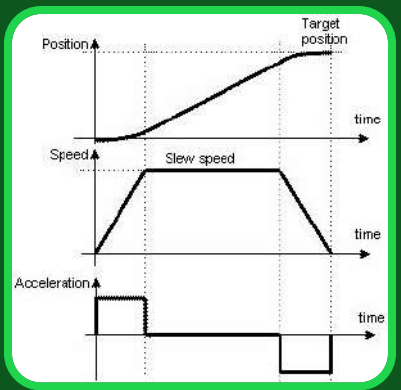


Lift Position Control

Problem: The lift needs a method of consistently moving to a target position for auto and teleop.

1st Solution: We implemented a **PID (Proportional, Integral, Derivative) feedback controller** to move the lift motors to a target encoder position when needed.
➤ **Quickly moved to the target.**
➤ **No limits on the output could cause violent motions.**

2nd Solution: We added a **trapezoidal motion profile** to the motion of the lift to smoothly accelerate and decelerate towards a target.
➤ **Motion profile generates a target velocity and position at a given time.**
➤ Controls acceleration and deceleration.
➤ Motion profiles are also used on our **virtual 4-bar servos to control shock loads.**



$$x(t) = x_0 + v_0 t + \frac{1}{2} a t^2$$

$$v(t) = v_0 + at$$

Equations that are used to find the target position and velocity at any time in the profile.

Intake Proximity Sensor

Problem: Low visibility at the front of the robot makes it difficult for drivers to see if a cone is in the intake.
Solution: We use a **Rev 2M TOF distance sensor** to determine the presence of a cone.

Servo Absolute Encoder

Problem: Timing claw actions is difficult with the virtual 4-bar since they have to happen at certain points in its rotation.

Solution: The AXON Max+ servos on our v4b have **analog absolute encoders,** allowing us to read their exact positions at any time.