#24085

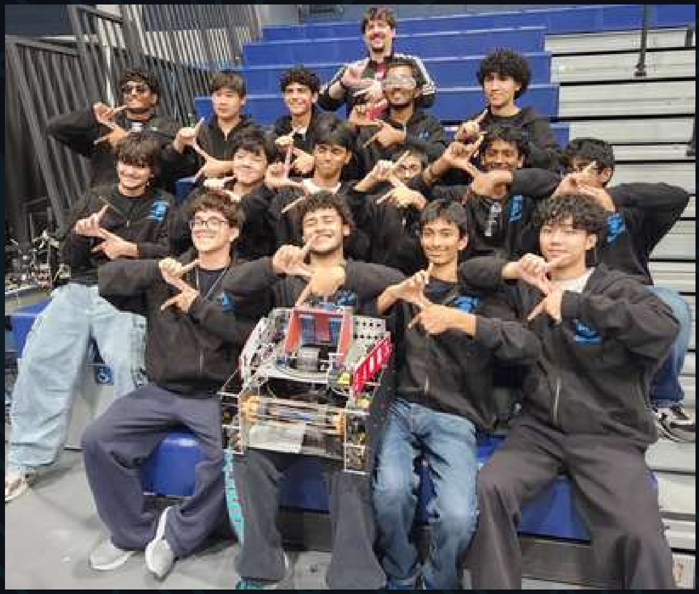
SHORT CIRCUIT

WHERE SPARKS IGNITE INNOVATION

ENGINEERING PORTFOLIO

2025-2026

MEET SHORT CIRCUIT!



TEAM INTRODUCTION

We are FTC Short Circuit #24085 from Orlando, Florida. Founded in 2023, our team is student-led and dedicated to engineering innovation, community impact, and global connection.

MECHANICAL:

HAVISH UPPADA (LEAD)
GABRIEL CHEN
NASSER AWADALLAH
JUAN ALCALA
ANDREW LUONG
SURAJ ANGADI
JOAQUIN DULANTO
JAVIER RIVERA
PARTHA BALAJI

BUSINESS/OUTREACH:

AKASH SALAPAKA (LEAD)
DOMINIC LAMMARDO
YUSUF AGLORIA
DANIEL MENG

PROGRAMMING:

VAIBHAV PRADEEP (LEAD)
SUMAEDH KATURU

OUR SEASON GOALS

TEAM:

- Reflect on tasks after every meet and competition.
- Assist rookies and teach them as much as possible.
- Communicate more effectively with sister/school teams.

COMMUNITY:

- Host at least 3 community STEM outreach events.
- Connect with 10+ FTC teams (4+ international) to discuss plans and visions for robotics.
- Mentor around 3-4 teams.
- Reflect on ourselves after meets, scrimmages and competitions.

ROBOT:

- Successfully create a robot with sorting capabilities.
- Enable fast and accurate scoring throughout the match.
- Design efficient and repeatable cycle paths to maximize performance.
- Ensure resilience to light defense and field variability.
- Develop an auto-aiming turret.

AWARD SUMMARY

INSPIRE AWARD
WE EXCEL IN ROBOT PERFORMANCE, DOCUMENTATION, OUTREACH, AND **DEMONSTRATE THE FIRST CORE VALUE**

THINK AWARD
- WE USE A CLEAR **ENGINEERING DESIGN PROCESS** WITH TESTING AND **ITERATION**, FULLY DOCUMENTED.

CONNECT AWARD
- MENTORED BY **INDUSTRY PROFESSIONALS** IN SOFTWARE AND AEROSPACE.
- COLLABORATED WITH **7+** FTC TEAMS.
- REPRESENTED FIRST AT **STEM EXPOS** AND **CONFERENCES**.
- APPLIED ROBOTICS TO **HEALTHCARE** AND **RESEARCH** PROJECTS.

MOTIVATE AWARD
- FOUNDED **SHORT CIRCUIT ACADEMY** TO TRAIN NEW MEMBERS.
- HOSTED K-8 **CODING CAMP**; RECRUITED FUTURE PROGRAMMERS.
- RAISED **$20K+** SINCE 2023; OPEN-SOURCED SPONSOR EMAIL SYSTEM.
- **MENTORED** LOCAL AND **INTERNATIONAL FTC/FLL TEAMS**

DESIGN AWARD
- **INTAKE EVOLUTION**: RUBBER BAND → COMPLIANT → VECTOR.
- CNC **LIGHTWEIGHT SIDEPLATES**; DRIVETRAIN REVAMP.
- 312 → 435 RPM MOTOR UPGRADE FOR FASTER CYCLES.
- PIDF-CONTROLLED 6000 RPM SHOOTER WITH FIRE-INHIBIT.

CONTROL AWARD
- **FINITE STATE MACHINE** INTEGRATES INTAKE → SORT → SHOOT.
- **ONE-BUTTON RAPID FIRE** OPTIMIZATION.
- AUTONOMOUS RETRIES + **FAIL-SAFE PARK**.
- FULLY **PID-TUNED DRIVE** AND TURRET CONTROL.

INNOVATE AWARD
- **BEARING-STACK TURRET** FOR SHOOTING WHILE MOVING.
- AUTOMATED **COLOR-SORTING SPINDEXER** (MULTI-SENSOR).
- POWER-MODELED FLYWHEEL + **ADJUSTABLE HOOD**.
- **DUAL AUTOS** USING SHARED **FSM FRAMEWORK**.
- ODOMETRY + **VISION SENSOR FUSION**.

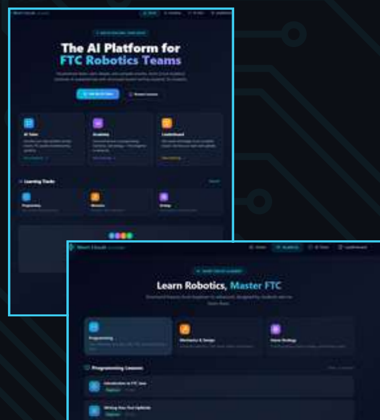
SUSTAINABILITY

Short Circuit is committed to **long-term sustainability** through leadership development, financial planning, and outreach. Veteran members **mentor newer students** in programming and mechanical design to **ensure knowledge transfer each season**, supported by organized documentation and shared code. We maintain financial stability through **sponsorships, grants, and fundraising efforts**.

SHORT CIRCUIT ACADEMY

Short Circuit Academy is a **fully developed AI training platform** now used by teams across the FIRST community. We share it with teams we connect with and provide it to **teams worldwide** to strengthen their foundation.

- Teaches **strategy, programming, and mechanical fundamentals**
- Accelerates **rookie member development** within our team
- Builds **technical confidence early in the season**

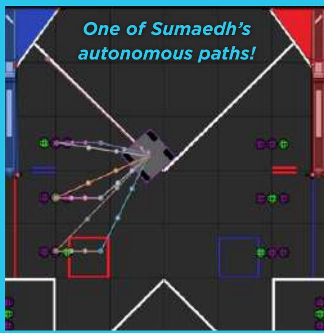


RECRUIT TRAINING

Team Short Circuit **trains** new recruits through **hands-on mentorship** in programming and electrical. Programmers learn **Java**, **Pedro Pathing**, and **sensor fusion**, while mechanical members focus on **wiring**, **CADing**, and **troubleshooting**. This **cross-training** helps students understand how hardware and software work together in the FIRST Tech Challenge robot.

"[Vaibhav's] mentoring helped me so much. I started the season unfamiliar with FTC Java, and now I'm able to contribute to our programming and autonomous pathing systems."

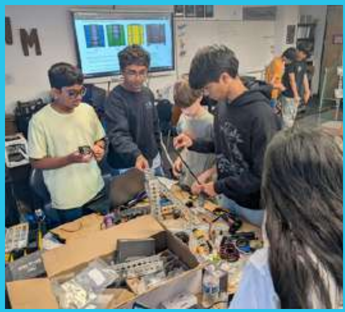
- Sumaedh (Programmer)



OSS/SHORT CIRCUIT CAMPS

OSS ROBOTICS CAMP

Every summer, Short Circuit hosts a **robotics camp** at OSS where students build and compete with robots. Through our mentorship, **over 80% join a robotics program**, and two new members were recruited **directly to our team** from this camp.



SHORT CIRCUIT CODING CAMP

After earning **first place for the Control Award**, we hosted a **six-week** Short Circuit Coding Camp **teaching FLL and FTC programming** to K–8 students. The camp **generated $300 for outreach** and helped us **recruit a new coder, Sumaedh**, strengthening our programming team.

FINANCE

Short Circuit maintains **long-term financial sustainability** through disciplined planning and budgeting.

- Carry over **$2,000–$2,500** each year to start strong
- Secure funding through **sponsors, grants, and fundraising**
- Practice **strategic purchasing** and reuse components when possible

This approach keeps us competitive while ensuring stable, sustainable growth.

Item	Income
Sponsorships	**+ $2,000**
FTC Grants	**+ $3,000**
Fundraisers	**+ $3,000**
Fees	**+ $2,250**
Total Income	**+ $10,250**

Item	Expenses
Outreach (From our own pocket)	**- $6,500**
Competition Fees	**- $300**
Robot Parts	**- $3,000**
Total Expenses	**- $9,800**

MARKETING/CONNECT

This year, we engaged with teams **worldwide** to **share ideas and learn** from **diverse perspectives**, growing through our shared passion for robotics. We **connect** with many teams via Instagram, where we have **600 followers** and average **over 37k views**.

We built a **team website** to showcase our robot and outreach, **support** recruitment and sponsorship, and serve as a **central hub** for judges, sponsors, and new members, driving **long-term growth**.

OPEN-SOURCED & PROVIDED PERSONALLY TO MANY TEAMS, SUCH AS

Heatwaves FTC Robotics TEAM 26192

SHORT CIRCUIT AUTO-EMAIL SYSTEM

$27K+
RAISED SINCE 2023

Our team secures **sponsors** by reaching out to local businesses through calls, emails, and community connections. We created an **automated daily email system** that helped us **gain three sponsors** and later made it **open source for other FIRST teams** to use and adapt.

THANK YOU TO OUR SPONSORS!

InStyle FASHION, INC.

OCTABLUE TECHNOLOGIES

GENE HAAS FOUNDATION

MENTORING

FLL TEAMS

We mentored **Robo Rockstars** and **Optimistic Orcas**, guiding them in programming and engineering fundamentals. Through our support, **Robo Rockstars advanced to Internationals** and won the **Design Award**, while both teams **strengthened** their **STEM skills** and confidence.

FTC TEAMS

We officially **mentor Viper Bolts**, providing guidance on team structure, starter robot design, and **long-term development**. We also **supported Quant 21062** with **turret programming**, strengthening the **global FIRST community** through collaboration and **shared** technical **expertise**.

OSS TEAMS

- Built a strong network of **seven FTC teams**, creating a resilient **support system**.
- Teams **share knowledge** in hardware, software, strategy, and development, reflecting **Coopertition and Gracious Professionalism**.
- Strengthens the **local FTC community**.

OUR INDUSTRY CONNECTIONS

MR. WHITFIELD

COACH AND SPONSOR WITH A MASTER'S IN PHYSICS AND TWO YEARS TEACHING PLTW ENGINEERING. TAUGHT FUSION 360 TO IMPROVE CAD AND BUILD EFFICIENCY AND CONTRIBUTED TO **STRONGER ROBOT PERFORMANCE**.

ESHA RANADE (FTC/FRC ALUMNI)

SUPPORTED OUR TEAM WITH **PROGRAMMING**, HELPED WITH **SENSOR FUSION**, AND BROUGHT **WORLD CHAMPIONSHIP EXPERIENCE** AND EXPERTISE AS A RECENT MIT COMPUTER SCIENCE GRADUATE.

MR. KOSURI

FOUNDER & CHIEF ARCHITECT AT OCTABLUE TECHNOLOGIES WITH A B.TECH IN COMPUTER SCIENCE. **OPTIMIZED ROADRUNNER PATHS** AND ODOMETRY FOR PRECISE NAVIGATION AND HELPED SECURE SPONSORSHIPS WHILE IMPROVING ROBOT SOFTWARE PERFORMANCE.

MR. ROSS

ROSS TIERNEY, FOUNDER OF ORBITSEDGE, HELPED OUR FTC TEAM BY SHARING ADVANCED PROBLEM-SOLVING AND SYSTEMS-THINKING STRATEGIES FROM SPACE TECH, HELPING IMPROVE **ROBOT DESIGN AND TEAM PERFORMANCE.**

OUTREACH

"WHERE SPARKS IGNITE INNOVATION!"

We **ignite curiosity** and **confidence** in STEM through robotics, mentoring, and community, **empowering the next generation** and strengthening our **community**.

PROMOTING FIRST

MAKER FAIRE

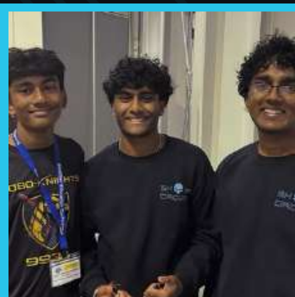
At the 2025 Maker Faire, we **represented FIRST** through live robot **demonstrations** and hands-on **activities** that engaged families and **inspired** interest in STEM. We also met **Viper Bolts**, whom we continue to **mentor today**, strengthening the **FIRST community** through collaboration and Gracious Professionalism.

PLTW SHOWCASE

At the **PLTW Showcase**, we demonstrated how classroom engineering concepts **connect to FTC** success through CAD, the design process, and strategic decision-making. We presented to **FOX 50**, the owner of **Discovery Education Services**, and local officials including the **mayor**, advocating for **STEM and showcasing the impact of FIRST**.

SMALLSAT EDUCATION CONFERENCE

At the SmallSat Education Conference at **NASA** Kennedy Space Center, we ran a FIRST outreach booth with a live robot **demonstration** and connected with **industry professionals**. There, we met **Mr. Ross**, whose guidance and connections continue to **support our team's growth**.



CURRICULUM NIGHT

At Curriculum Night, we represented FIRST Tech Challenge through a live robot **demonstration**, **introducing families** to robotics and **STEM opportunities**. This event **increased** FTC awareness, supported team recruitment, and **strengthened our school's STEM community**.

MONTESSORI SCHOOLS

We conducted outreach at local Montessori Schools, delivering **presentations** about FIRST, hosting live robot demonstrations, and leading interactive **STEM activities**. Through this engagement, we aimed to **inspire early interest** in robotics and expand **awareness** of **FIRST programs**.

FTC SCRIMMAGE

We **volunteered** at our school's **FTC Scrimmage**, supporting setup, field operations, and teams while demonstrating **leadership** and **Gracious Professionalism**.

FOOD TRUCK

We volunteered at a local food truck and **Hindu temple**, combining **community service with STEM outreach** while promoting FIRST and demonstrating Gracious Professionalism beyond competition.

HELPING CLUBS

We supported many **fellow clubs** within our school, including **Odyssey of the Mind**, by providing **custom 3D-printed parts**, helping them earn **1st at Regionals and advance to States**.

SHORT CIRCUIT IN HEALTHCARE

“WHERE INNOVATION MEETS COMPASSION!”

We **apply engineering** and robotics to support the healthcare community: creating tools, outreach initiatives, and partnerships that bring **technology-driven solutions** to patients, providers, and **future medical innovators**.

AWARENESS

THE GOLDEN MARROW PROJECT

Short Circuit partnered with a nonprofit focused on **leukemia awareness,** we plan to host community events featuring our robot and **interactive mini-games**. Through these events, we **combine robotics and advocacy** to help **raise awareness** about leukemia and the importance of donor registration.

RISE X SHORT CIRCUIT

We partnered with the **student club RISE** to visit a **children’s hospital**, where we created and shared custom **3D-printed trinkets, keychains, and small gifts** for patients to enjoy. Through this outreach, we aimed to **inspire curiosity** and share **the values of FIRST** by bringing **creativity, engineering, and hands-on making** to students in a **meaningful community setting**.

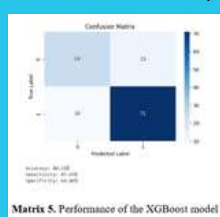
RESEARCH PROJECTS

OPTIMIZED LATTICE DENTAL IMPLANTS

We supported a **regional science fair project** on lattice-designed dental implants to reduce stress shielding by **teaching CAD and Onshape**. The project earned **2nd place** in its category.

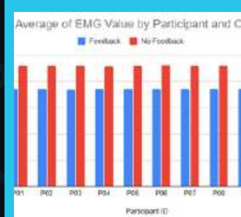
AI IN PANCREATIC CANCER

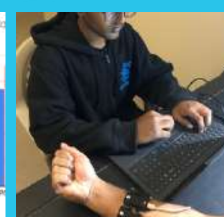
We supported another research project focused on using **AI models to detect** pancreatic cancer early. We **applied our programming experience** to help **develop and implement** the machine learning code, strengthening the technical execution of the project.



NEUROADAPTIVE DEVICE

Team member **Havish** applied his **robotics skills** to develop a **low-cost neuroadaptive wearable** using real-time EMG detection and vibrotactile feedback to **reduce excessive muscle activation** during grip tasks, showcasing **robotics applied to healthcare**.





HELPING LOCAL CLINICS

VET CLINIC

Pet Care Center of Apopka

We partnered with a local veterinarian clinic to design and 3D print custom pet accessories, including **dog tags and leash holders**, which were distributed to pet owners, applying our **engineering skills to support the community**.

CLINIC & PHARMACY

We partnered with **Rite Med Pharmacy, Pro Med Physicians, Women's Health Specialists of Central Florida,** and the **Maxillofacial and Reconstructive Surgery Clinic** to **enhance patient care.** Using STEM, we designed and 3D printed fidgets, toys, and assistive tools to **improve comfort and accessibility** for patients, including the elderly.

SHORT CIRCUIT'S GLOBAL NETWORK

"WHERE INNOVATION KNOWS NO BORDERS!"

We expand access to **STEM worldwide** through international partnerships, **sustainable** programs, and **collaborative** outreach that **empowers students** across the globe.

NSRI RESEARCH

This season, our team was **selected** for a **limited international research collaboration pilot**, recognizing the **originality** of our work. Through this program, we are **partnering** with a **global research organization** and an **international researcher** to strengthen our **methodology**, **analysis**, and **presentation**. This experience enhances our **competitiveness and supports scalable global collaboration in FTC**.

400+

CHAPTERS

THIS COLLABORATION SPANS

50+

COUNTRIES, CONNECTING STUDENTS AND TEAMS AROUND THE WORLD.

LEADING UNIVERSITIES

Columbia University, GT, Emory University, Massachusetts Institute of Technology

CONNECTING GLOBALLY

To expand global collaboration, we connected with **over 78 teams** across **70+ countries**, exchanging ideas and strengthening **international relationships** within FIRST. Through these conversations, we successfully **recruited 30%** of those teams into our **FTC In-a-Box program**, **accelerating global access to STEM**.

connected accross

77+

countries

IN-A-BOX PROGRAM

This season, we launched the **FTC In-a-Box Program,** a **global initiative** to lower financial barriers for starting FTC teams. In **collaboration with international** FIRST teams, we designed **$2500 starter kits** containing essential drivetrain components, and our first kit is currently **in transit to California.** Partnerships are established as we prepare for **broader distribution**.

Through this initiative, we are building a sustainable model that **promotes equity, accessibility, and long-term growth** within FIRST.

In the future we are planning on making **fully 3d-printed robots** to increase the sustainability and also increase amount of teams started.

PARTNERED WITH

25+

INTERNATIONAL TEAMS FROM: CANADA, ROMANIA, ETC.

KIT

EACH KIT VALUED AT

$2500

FTC Short Circuit

PROJECT TAIWAN

A year-long, **ongoing initiative** led by Short Circuit, collaborating with **multiple schools** across Taiwan to introduce FIRST robotics programs where such opportunities previously **did not exist**. To date, we have worked with **5+ elementary, middle, and high schools**, building sustainable robotics programs and expanding equitable access to **STEM education**.

We traveled across **Taiwan** to **underserved regions**, hosting **adaptive robotics camps** for elementary through high school students and teaching **FIRST programs**, general robotics, and **hands-on FTC workshops**. Our programming team created a complete **coding curriculum** and delivered FLL and FTC instruction, including remote lessons via **Zoom**.

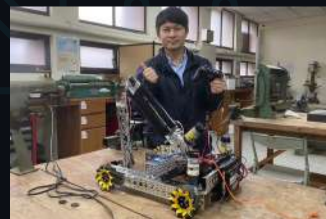
To ensure sustainability, we partnered with a **local university and an FRC alumni team**, leaving behind our robot, curriculum, and resources so the initiative could **continue independently**. We later returned during winter break to support instruction and **evaluate progress, reinforcing long-term impact**.

300+
CHILDREN TAUGHT

8+ DIFFERENT SCHOOLS

WORKED WITH **NATIONAL TAIWAN NORMAL UNIVERSITY** FRC ALUM

$40,000+
WORTH OF MATERIALS DONATED



STATS SUMMARY

150+
FTC TEAMS COLLABORATED WITH

20+
STEM EVENTS

PARTNERED WITH
25+
TEAMS FOR IN-A-BOX

TAUGHT
650+
CHILDREN HELPED

$40k+
IN DONATED MATERIALS

61+
COUNTRIES PARTNERED WITH

$27K+
RAISED SINCE 2023

7 FLL TEAMS

FIRST LEGO LEAGUE

25+
SCHOOLS VISITED

44
STATES REACHED OUT TO

DESIGN PROCESS AND PROGRESSION

HARDWARE

MEET ONE

- INTAKE SYSTEM USING SURGICAL TUBING; DESIGNED FOR FUTURE AUTOSORTING INTEGRATION.
- TRANSFER SYSTEM WITH MULTIPLE SMALL WHEELS AND A GUIDING LEVER TO FEED BALLS INTO THE SHOOTER.
- SHOOTER POWERED BY A 6000 RPM MOTOR WITH A 3:2 GEAR RATIO.
- ADJUSTABLE HOOD WITH UP TO 90° OF ROTATIONAL RANGE.

MEET TWO

- FULL DRIVE TRAIN REVAMP
- NEW CNC'D SIDEPLATES TO GREATLY REDUCE WEIGHT AND STRUCTURAL STABILITY

V1: SHOCK'ILLE O'NEAL

MEET THREE

- ADDED POLYCARBONATE SIDE PLATES TO IMPROVE STRUCTURAL STRENGTH AND DEFENSE.
- REDUCED BELT TENSION TO LOWER DRIVETRAIN MOTOR LOAD.
- SWITCHED FROM 312 RPM TO 435 RPM MOTORS TO IMPROVE CYCLE TIME.

LEAGUE CHAMPIONSHIP

- ADDED SENSOR TO INTAKE MORE SEAMLESSLY
- INTAKE MOTOR RPM DECREASED TO NOT DRAIN VOLTAGE
- SMOOTHER TURRET IMPLEMENTATION WITH BETTER SNAPBACK EFFECT

V2: KAVIKESHAVAN (KEVIN)

SOFTWARE

MEET ONE

- DRIVETRAIN BRAKING FUNCTION ADDED WITH HOLONOMIC ABILITIES
- CONTINUOUS SERVO IMPLEMENTATION FOR SPINDEXER
- MOTIF DETECTION WITH HUSKY LENS VISION

MEET TWO

- PIDF TUNED SPINDEXER WITH DISTANCE SENSOR LOCALIZATION
- SIMPLE AUTONOMOUS SYSTEM WITH SEMI RAPID SHOOTING

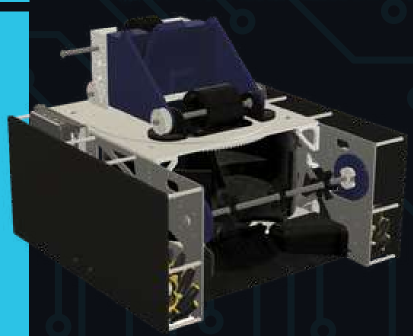
MEET THREE

- IMPLEMENTED PEDRO PATHING WITH PARAMETRIC CALLBACKS FOR INTEGRATED AUTONOMOUS ACTIONS.
- PIDF-TUNED SHOOTING SYSTEM FOR IMPROVED ACCURACY AND CONSISTENCY.
- DESIGNED FINITE STATE MACHINE ENABLING ONE-BUTTON RAPID SHOOTING OPTIMIZATION IN TELEOP.

LEAGUE CHAMPIONSHIP

- CODED SWITCHBACK TURRET FOR AUTONOMOUS AND TELEOP.
- OPTIMIZED AUTONOMOUS CYCLING VIA PARAMETRIC CODE IMPROVEMENTS.
- CREATED AUTOMATED SPINDEXER WITH DISTANCE SENSING AND COLOR/VISION SORTING (HUSKYLENS).

V3/4: KA'WIRE LEONARD



V1: SHOCK'ILLE O'NEAL

STRENGTHS: DEFENSIVE CAPACITY DUER TO HEAVY BUILD.

WEAKNESSES: SLOW SPEED DUE TO OVER-TENSIONING OF BELTS, COORDINATING INTERNAL MECHANISMS.

V2: KAVIKESHAVAN (KEVIN)

STRENGTHS: FASTER DRIVE-TRAIN AND CYCLE TIMES IMPROVED INTAKE.

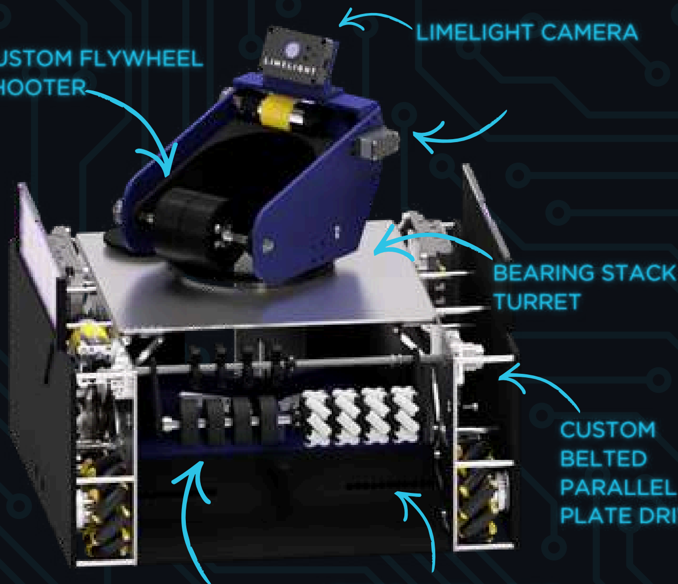
WEAKNESSES: HIGH VOLTAGE SENSITIVITY BY SHOOTER DURABILITY OF SIDEPLATES.

V3/4: KA'WIRE LEONARD

STRENGTHS: POLYCARBONATE SIDEPLATES, FASTER DRIVETRAIN MOTORS, AND A SLOWER, VOLTAGE-EFFICIENT INTAKE MOTOR.

WEAKNESSES: CYCLE TIMES
CLOSE/EXTENDED AUTO AND SORTER INTEGRATION
AUTONOMOUS INTAKES FROM HUMAN PLAYER ZONE
LEVER INTEGRATION.

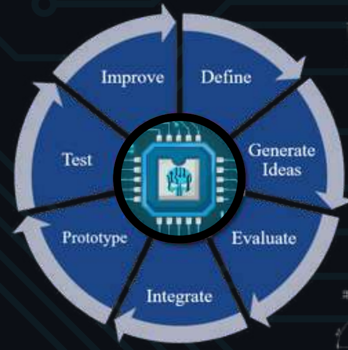
MEET ZEUS!



ENGINEERING DESIGN PROCESS

OUTTAKE

EARLY SEASON CAD



KA'WIRE LEONARD V4

SHOOTER HOOD MEASUREMENTS

RISK MANAGEMENT & MITIGATION

To reduce issues with our robot, we use focused strategies:

- **CAD** before ordering and assembling systems.
- Keep **spare components** and **alternative** routines ready.
- **3D-print** and **test** subsystems like intake and shooter.
- **Test** the robot through **repeated** matches for **durability**.

DESIGN CONSIDERATIONS

SPINDEXER

STRENGTHS: AUTOMATICALLY SORTS PIECES FOR MORE POINTS.

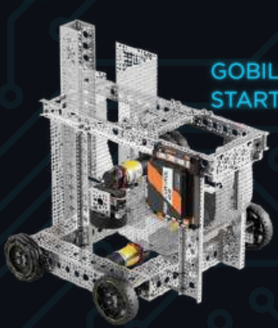
WEAKNESSES: SLOWER CYCLE PRONE TO JAMS.

DIRECT-FEED

STRENGTHS: SIMPLE SHOOTS QUICKLY.

WEAKNESSES: NO SORTING, REQUIRES PRECISE DRIVER ALIGNMENT.

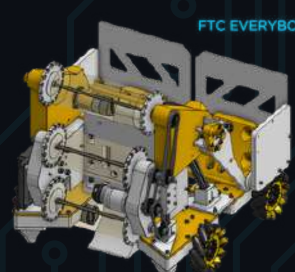
HOPPER



STRENGTHS: STORES AND FEEDS MANY PIECES EFFICIENTLY.

WEAKNESSES: CAN JAM AND ADD EXTRA WEIGHT.

CATAPULT



STRENGTHS: SCORES FROM DISTANCE, AVOIDS DEFENSE.

WEAKNESSES: HARD TO TUNE, TIMING CRITICAL.

GAME STRATEGY

AUTO

- Turret implementation allowing for shooting from **many orientations**
- Focusing slightly more on **long auto** due to **over-specialization** of most teams in the short area

TELEOP

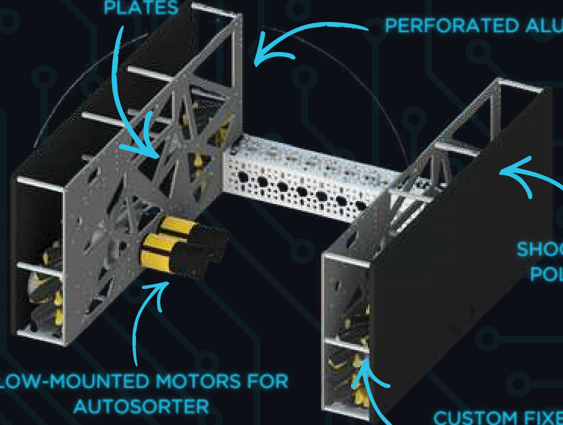
- Focus on **far shooting** due to our sorter robot **not** being able to **rapidly shoot**
- **Cycling** human player zones
- **Minimize** time wasted **revving** motor

ENDGAME

- Continue **cycling sorted** balls in order to score **motifs**
- Complete a **partial park** while **alliance** completes **full park**.

FTC Short Circuit

DRIVETRAIN



Drivetrain type	Cost	Motility	Game-Specific Performance	Traction	Time	Total
SWERVE	1	5	5	4	2	17
TANK	5	1	2	5	5	18
MECANUM	3	5	4	3	4	19
X-DRIVE	3	4	3	2	3	15

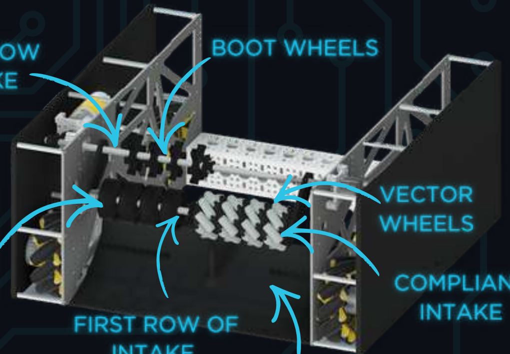
FEATURES

- We used a **belt driven mecanum** drive since it increases **mobility** without greatly **increasing cost**.
- The mecanum wheels allow for **strafing and diagonal** movement which **broadens** the capabilities of our bot

ITERATIONS

- We **iterated** by removing the **miter gears** in our first drive train to **prevent slippage**.
- We also had **custom motor mounts** that led our motors to **slip** around.
- We put the motors on **quad blocks in future designs**.

INTAKE



HOW DOES THE COMPLIANT ARM INTAKE WORK?

- The **compliant arm** is connected to another **stationary bar** about which it **rotates**.
- This rotation allows for some **flexibility** while **intaking** balls
- The mechanism is powered by a **motor** that **drives both bars,** which are **chained together**

ITERATIONS

- We shifted from a **rubber band based** intake on a **static bar** to a compliant bar intake.
- The rubber bands **frequently broke** while a **compliant intake** would **remain sturdy** and improve cycle time by **50%**

VECTOR WHEEL INTAKE

STRENGTHS: FAST, STRONG CENTERING, CONSISTENT

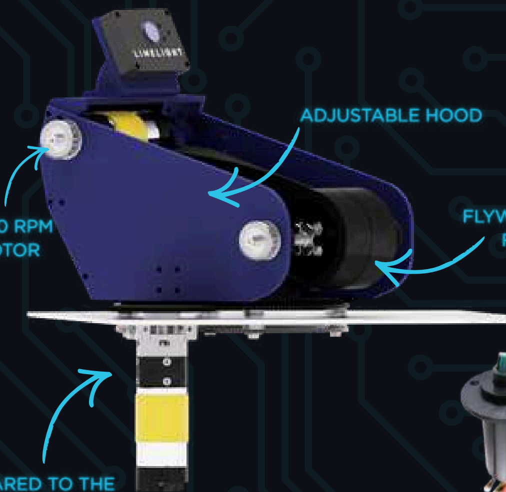
WEAKNESSES: HEAVIER MORE COMPLEX PRICIER

RUBBER BAND INTAKE

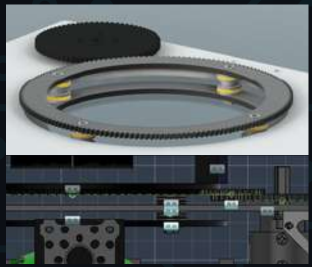
STRENGTHS: LIGHT, CHEAP, COMPLIANT

WEAKNESSES: WEARS OUT LESS CONSISTENT

TURRET



BEARING STACK



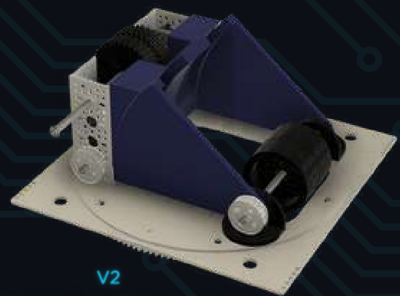
- Our **bearing stack** design allowed for a **custom bearing size** that we could **iterate** throughout the season
- Its **modularity diversified** our design **possibilities** since we could decide to include **more or less bearing stacks**

- Used **4 slip rings** to allow continuous rotation without tangling wires
- Slip rings functioned perfectly during testing and matches
- Adding a switchback mechanism improved **auto alignment by 70%**

WHY TURRET?

- Enables **shooting while moving**, making it **easier** for drivers to **score in scoring zones**
- **Reduces cycle time** by **automatically aligning** the shooter to the target when in range
- **Expands scoring angles** during autonomous, increasing **flexibility** and **saving time**

V1

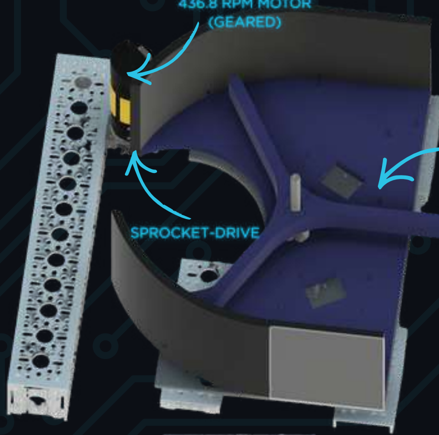


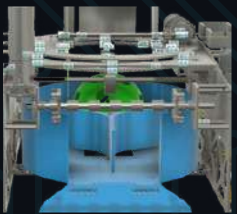
V2

TURRET ITERATIONS

- We iterated by **reducing** the size of the **bearing** in order to **better manage our wires**.
- We added **steel flywheels** in order to **increase the inertia** and **reduce** our **revving** times
- The flywheels' **gear ratio** was reduced from **3:2 to 1:1** in order to **apply more torque** onto the wheels (since they now **weighed more**)

SPINDEXER





V1

V2

TURRET CALCULATIONS

ROTATIONAL DYNAMICS

$$\tau = I\alpha$$
$$I = mr^2$$
$$I = \frac{1}{2}mr^2$$
$$I = I_{cm} + md^2$$
$$\tau_{total} = I\alpha + \tau_f$$

CENTRIPETAL FORCES

$$F_c = mr\omega^2$$
$$a_c = r\omega^2$$
$$F = ma$$

ANGULAR KINEMATICS

$$\omega = \frac{d\theta}{dt}$$
$$\alpha = \frac{d\omega}{dt}$$
$$\omega = \omega_0 + \alpha t$$
$$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$$
$$\omega^2 = \omega_0^2 + 2\alpha\theta$$

WHY SPINDEXER?

- Adds **sorting** capabilities to **improve** game piece **handling** and **scoring** efficiency during autonomous
- Enables **easier integration** of **sensors** (e.g., color and distance) to improve **performance** in both teleop and autonomous

SPINDEXER ITERATIONS

- Modified the spinning arm assembly to **allow intaking** while in the **outtake position**, **helping transition** between scoring and collecting.
- **Increased clearance** to improve the **effective intake angle**; more **consistent pickups** from various approach **vectors**.

SOFTWARE: SENSOR FUSION, SPINDEXING SYSTEM

COLOR SENSOR

- Mounted **three color sensors** on the spindexer to improve identification of different colored artifacts
- Enables **automated color-based distribution** during both Telep and autonomous, **reducing driver workload** and improving cycle efficiency
- Helps maintain **fast scoring cycles** without sacrificing accuracy and having **motif oriented scoring**

DISTANCE SENSOR

- Mounted **three distance sensors** parallel to the color sensors on the spindexer to detect when an artifact is fully inside the robot
- Reduces the chance of **partial intake**; if detected, the system automatically reverses the intake to clear obstructions
- Indexes balls in each of **three slots**, so if a ball is in the slot in front of intake, it will **automatically move it out** of the way
- Provides consistent **artifact detection** as a fallback when the color sensor detects parts of the robot instead of a game piece

FILTERED DISTANCE ESTIMATION MODEL

$$d = \frac{c \cdot t}{2}$$

$$d_{\text{filtered}}(k) = \alpha\, d_{\text{raw}}(k) + (1-\alpha)\, d_{\text{filtered}}(k-1)$$

$$|d_{\text{filtered}} - d_{\text{in}}| < \tau_d$$

$$d_{\text{partial}} < d_{\text{filtered}} < d_{\text{in}} \quad \text{for} \quad \Delta t > T_{\text{jam}}$$

DISTANCE-BASED COLOR CLASSIFICATION SYSTEM

$$c = (R, G, B)$$

$$\hat{c} = \frac{c}{\|c\|} = \frac{(R, G, B)}{\sqrt{R^2 + G^2 + B^2}}$$

$$d_{\text{green}} = \|\hat{c} - \hat{g}\|$$

$$d_{\text{purple}} = \|\hat{c} - \hat{p}\|$$

$$\text{Artifact} = \begin{cases} \text{GREEN}, & d_{\text{green}} < d_{\text{purple}} \text{ and } d_{\text{green}} < \tau_c \\ \text{PURPLE}, & d_{\text{purple}} < d_{\text{green}} \text{ and } d_{\text{purple}} < \tau_c \\ \text{UNKNOWN}, & \text{otherwise} \end{cases}$$

FINITE STATE MACHINES

- **Finite state machines** use a switch-case structure where each case is an enum state. Each state runs until a condition is met, then switches to a **new state** to perform a different action.
- **Pedro Pathing:** Switches between **states** so specific **actions** (like sorting or intaking) run during each **path**.
- **Indexing:** Manages indexing states, automatically moving a ball after intake to free the slot, or checking ball color in the last 30 seconds before moving to outtake.
- Shooting Sequence: Integrates the lever, sorter, and shooter—after the sorter moves, the lever raises once the shooter reaches velocity—automating the process for fast and consistent shooting.
- **HuskyLens Vision:** Detects balls to **improve** teleop **performance**. In auto, it uses object detection to align precisely with balls, allowing smooth, straight-line intake.
- **Gamepad Optimization:** After Meet 2, intake controls were changed to a toggle system—press once to start and press again to stop—allowing faster and more efficient driver control.

SOFTWARE: PEDRO PATHING/ AUTONOMOUS SYSTEMS

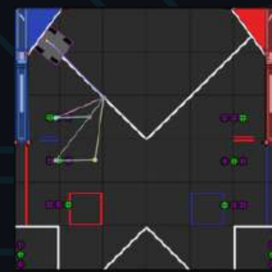
CHOICE: PEDRO PATHING

- Used Pedro Pathing to generate smooth, **spline-based** autonomous paths with reliable **path completion** detection
- Tuned and visualized the robot model to **avoid field elements**, improving pickup consistency and reliability
- Used **GoBilda Pinpoint odometry** (dead wheels) to track position and calculate velocity/acceleration
- PID tuned **centripetal**, **rotational**, **and translational control loops** for fast, accurate movement
- Used the **Pinpoint IMU** to track heading and rotational velocity for improved orientation accuracy
- **Pathing:** We use cubic Bézier parameterization with curvature-based velocity constraints and Frenet frame error projection for path tracking.

CLOSE VS. FAR AUTO ROUTINES

- Built separate close and far autos with multi-cycle routes (preload → rows → park)
- Used a **shared state-machine framework** with **timers, retry logic, and bail-to-park conditions**, allowing changes to transfer between both autos easily

FAR-SIDE AUTO



CLOSE-SIDE AUTO

MARROW

- Used an open-source library to provide **precise field localization** with **odometry**, allowing easy tuning of behaviors and reliable retry handling when inconsistencies occurred in Pedro
- Implemented **temporal callbacks** so if insufficient time remained in autonomous to shoot, the robot **automatically parked** in the final 5 seconds
- Added **automatic retries** if a ball row was not fully intaken or the target distance was not completed
- Implemented **area-based shooting** in teleop, allowing **shooting sequences** to run only when the robot was within **designated shooting zones**

ADDITIONAL SYSTEMS

- Used optimal pathing with **Bézier curve** calculations to create the shortest possible routes between waypoints
- Implemented controlled braking and measured deceleration to intake all three balls quickly without sacrificing consistency
- Used parametric callbacks to **trigger actions (e.g., sorting)** at specific path percentages, allowing tasks to run before a path fully completed and improving overall cycle speed

BEZIER CALCULATIONS

TIME PARAMETERIZATION

$$s(t) = \int_0^t \sqrt{\dot{x}(\tau)^2 + \dot{y}(\tau)^2}\, d\tau$$

ARC LENGTH

$$L = \int_0^1 \sqrt{\dot{x}(t)^2 + \dot{y}(t)^2}\, dt$$

FRENET FRAME

$$\mathbf{N}(t) = \frac{d\mathbf{T}/dt}{|d\mathbf{T}/dt|}$$

COMBINED POSITION CALC

$$\text{Robot Position} = B(t) + e_n \mathbf{N}(t)$$

CURVATURE CALC

$$\kappa(t) = \frac{\dot{x}(t)\ddot{y}(t) - \dot{y}(t)\ddot{x}(t)}{(\dot{x}(t)^2 + \dot{y}(t)^2)^{3/2}}$$

IMPORTANT CALCULATIONS

TARGET VELOCITY CALC.

$$v_t = \sqrt{-2 * a_t * s}$$

PIDF CONTROLLER CALC

$$u(t) = K_P e(t) + K_I \int_0^{\infty} e(\tau)\, d\tau + K_D \frac{d}{dt} e(t) + K_F r(t)$$

CUBIC BEZIER

$$\mathrm{M} = \begin{bmatrix} -1 & 3 & -3 & 1 \\ 3 & -6 & 3 & 0 \\ -3 & 3 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix}$$

ZERO POWER DECAY CALC

$$p_d = v_i - v_f$$

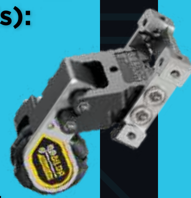
ACCELERATION CALC

$$B''(t) = 6(1-t)(P_2 - 2P_1 + P_0) + 6t(P_3 - 2P_2 + P_1)$$

SOFTWARE: CONTROL SYSTEM FOR TURRET & SHOOTER

TURRET: ODOMETRY/ LIMELIGHT

- **Odometry (goBILDA Pinpoint + odopods):** Calculates robot X/Y and heading to determine target angle and convert it to turret encoder ticks.



- **Limelight (AprilTag backup):** Used to re-center on the goal and reset odometry if IMU drift or localization errors occur.
- **PID Control:** Drives Limelight Tx to zero and moves the turret motor to target encoder ticks for accurate aiming.

- **Finite State Machine:** Defaults to odometry aiming, switches to Limelight relocalization when triggered, then returns once corrected.

TURRET: ODOMETRY/ LIMELIGHT

Kalman Filter (HuskyLens Vision):

- Detects balls to optimize teleop performance.
- In auto, uses object detection to locate balls and align precisely for smooth, straight-line intake.

Gamepad Optimization:

- Updated after Meet 2.
- Intake now toggles with the same button (press again to stop), allowing **faster and more efficient driver control**.

Kalman Filter Process:

- Predict: Uses the **robot's previous state** and a motion model to estimate its next position.
- Update: Incorporates new **sensor data**, balancing trust between the model and sensors using the **Kalman Gain**.
- Trusts the more reliable source (model or sensor) to improve **accuracy**.
- Provides precise state estimation for **localization**, **angle tracking**, and other **critical measurements**.

SHOOTER VELOCITY CONTROL

- **High-Velocity Flywheel (PIDF):** Uses velocity feedback from encoder ticks and motor speed to regulate shooter power. Tuned for fast spin-up, stable high RPM, and sustained performance. A "fire inhibit" state prevents shots until the flywheel reaches target velocity within tolerance.
- **Power Regression + Adjustable Hood:** Uses a custom regression model to select optimal shooter speed and hood angle, enabling accurate shots from anywhere in the shooting zone.

PREDICTION STEP

The state estimate is **predicted** using the **previous** state plus the expected change:

$$x_t = x_{t-1} + u_t$$

Along with this prediction, the uncertainty grows by adding the model variance:

$$\mathbf{p}_t = \mathbf{p}_{t-1} + \mathbf{q}$$

IMPORTANT CALCULATIONS

$I = M R^2$

T = I A

T_OUT = T_MOTOR × G × H

Ω_OUT = Ω_MOTOR / G

Ω = RPM × (2Π / 60)

Θ_RES = 2Π / (TICKS_PER_REV × G)

ERROR = TARGET - CURRENT

POWER = KP·ERROR + KI·Σ ERROR + KD·(ΔERROR/ΔT)

IF (OVERSHOOT) ↑KD
IF (SLOW) ↑KP
IF (STEADY_ERROR) ↑KI

// SHORTEST PATH (SWITCHBACK)
DELTA = TARGET - CURRENT
IF (DELTA > 180) DELTA -= 360
IF (DELTA < -180) DELTA += 360

ANGLE KINEMATICS

- **Rotational motion** and control equations describe systems like a **turret**.
- **Inertia** I=mr2I = m r^2I=mr2 determines how hard it is to change the **system's rotation**.
- **Torque** τ\tauτ causes **angular acceleration** through τ=Iα\tau = I \alphaτ=Iα.
- **Gearboxes** increase torque but reduce **rotational speed**.
- **RPM** is converted to **angular velocity** (radians/sec) for accurate **kinematic calculations**.
- Controllers compute **angular error** and use **PID** to apply corrective torque.
- **Angle wrapping** keeps rotation within **±180°**, ensuring the shortest rotation path.