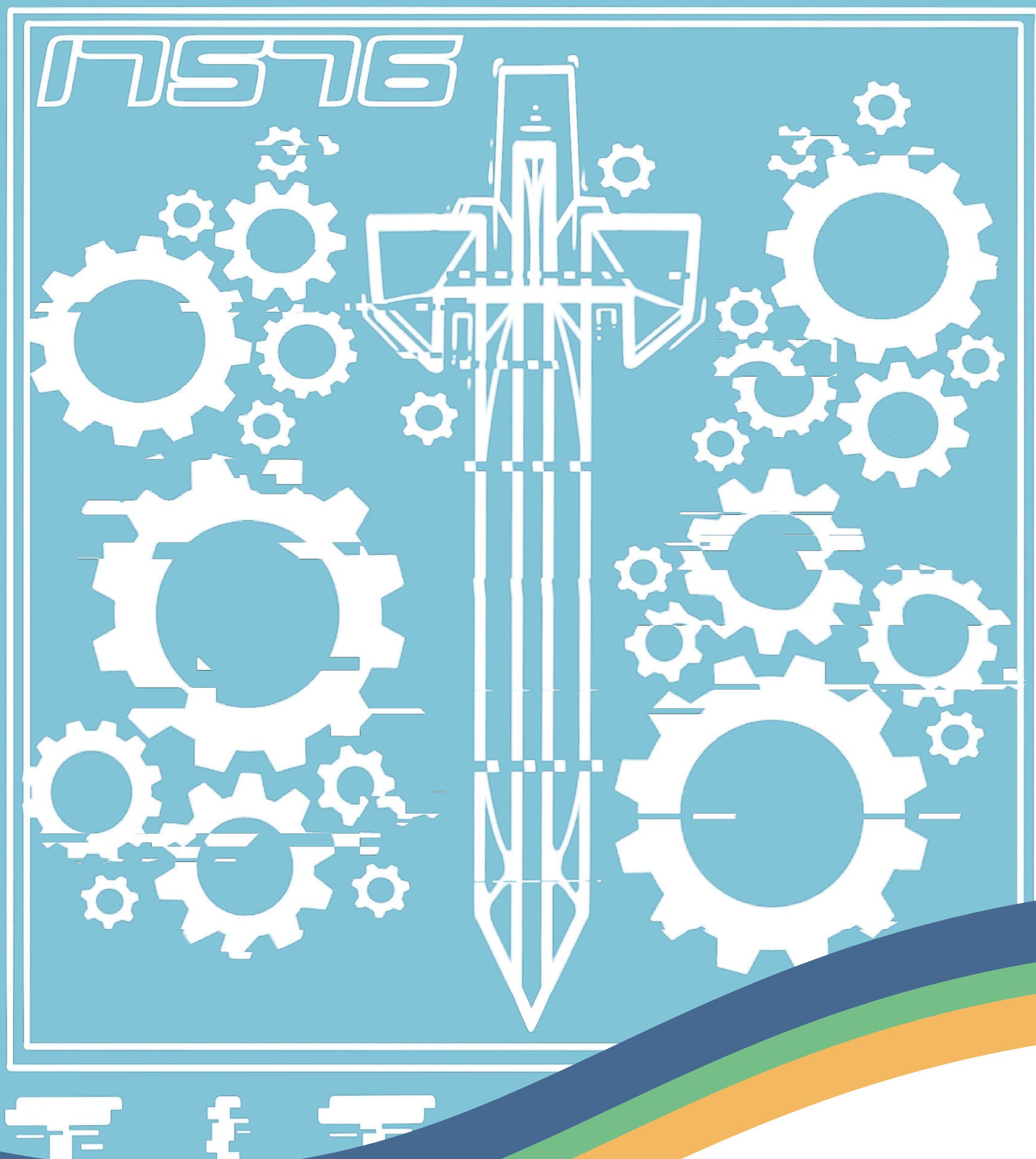
FTC TITANS #17576

ENGINEERING PORTFOLIO



POWER PLAY℠

PRESENTED BY Raytheon Technologies

TOMORROW'S INNOVATORS & THINKERS ACQUIRING NEW SKILLS

MEET THE TEAM

(Left to Right): David Mahler (Coach), Gautham Anne (Mech), Michael Meng (Software), Ebba Kaulas (Junior Captain;Outreach), Jayant Kumar (Captain; Mech), Neev Patel (Outreach), Ankit Walishetti (Mech); Not pictured: Shawn Crimmins, (Software))

Captain: Jayant Kumar ('23)
Junior Captain: Ebba Kaulas ('24)

MECHANICAL:
Gautham Anne
Jayant Kumar
Ankit Walishetti

SOFTWARE:
Michael Meng
Shawn Crimmins

OUTREACH:
Ebba Kaulas
Neev Patel

Coaches: David Mahler, Grant Bell

TEAM SUMMARY

TITANS was founded in Fall 2019 at the Illinois Mathematics and Science Academy in Aurora, IL.

Our team consists of 2 seniors, 2 juniors, and 3 sophomores.

MISSION STATEMENT

To dream of a future where we use science and technology to push the limits of the human condition by fostering curiosity, passion, and growth.

SUSTAINABILITY

RECRUITING

Members are recruited via an **application process** in September, after our presentation at **IMSA's annual Club Fair**. Inexperienced members are taught technical skills, such as CAD and programming, by veteran members through instructional videos created off-season. These skills are improved upon throughout the season by hands-on experience.

We recruit mentors by conducting demos and design reviews with corporate sponsors, community events, parents and school faculties. Among the notable mentors from our sponsors.

FUNDRAISING

- Obtain sponsors by emailing employees, presenting about our FIRST experience and accomplishments, and providing a sponsorship package.
- Maintained our relations with our sponsors and mentors through newsletters, feedback forms, email, and future meetings or design reviews.
- **Over $7,000** left in rollover funds for next year

TEAM FINANCIALS

ITEM	DESCRIPTION	INCOME & COST	BALANCE
Savings	Balance left over from previous year	$5638.74	**5638.74**
Sponsors	Caterpillar, Molex, IMSA, TE Connectivity	$4475.00	$10,113.74
Participation Costs	Registration, Game Elements, Shirts	-$1370.88	$8742.86
Robot Parts	Electronics, Mechanical parts & Tools	-$1058.65	$7,684.21
TOTAL			**$7,684.21**

GOALS & REFLECTIONS

- [ ] Accomplished Goals
- [ ] In-Progress Goals

COMMUNITY

- [ ] Reach 6000+ people
- [ ] Mentor at least 7 teams
- [ ] Obtain 100+ team hours

TEAM

- [ ] Teach the rookies as much as possible
- [ ] Reflect on tasks accomplished at the end of each practice
- [ ] Less miscommunication between subteams

ROBOT

- [ ] Build a turret bot by regionals
- [ ] Learn how to CNC parts on our machine
- [ ] Learn how to code a turret bot
- [ ] Have a successful Tele-Op

MEET REFLECTIONS

	WHAT WENT WELL	WHAT DIDN'T GO WELL	NEXT STEPS
MEET 1 Point Avg: x	○ Drivetrain was fast	○ No autonomous ○ Very little driver practice ○ Slow at navigating field ○ Wiring for lift broke between matches	○ Create a parking autonomous ○ Improve cycling speed through drivers practice and iterating on design
MEET 2 Point Avg: x	○ Lift was consistent ○ Scored multiple cones on high/mid/low junction	○ Auto did not function ○ Still very slow at grabbing cones ○ Claw was not grippy	○ Program auto to deposit loaded cone ○ Increase cycling time through new design ○ New claw design
MEET 3 Point Avg: x	○ Claw worked and never lost a cone or beacon ○ Scored multiple times ○ Driver practice allowed for faster cycling times	○ Auto was still inconsistent ○ Wiring was messy, causing issues during inspection and driving ○ Turret stopped functioning mid-match due to going to encoder position	○ Redesign lift(mounting points for lift motors) ○ Redesign turret to prioritize wiring ○ Program a more consistent autonomous

OUTREACH

PARTNERED WITH **14** ORGANIZATIONS

238 HOURS VOLUNTEERED

6317 PEOPLE MOTIVATED

CONNECTED WITH **59** PROFESSIONALS

497 INTERACTIONS ON SOCIAL MEDIA

"I am 100% sure that our students benefitted a lot from having an opportunity to experience the judging process in advance of the tournament.

-Jeremy Schwartz, Head of UChicago Lab Schools Computer Science

The presentations were so wonderful and I think you inspired many kids today.

-Ms. Woelflie, Orrington Elementary Admin

I wanna build a robot today! ... As big as Jupiter!

-Excited Kindergartener, Primary School (Daegu, South Korea)"

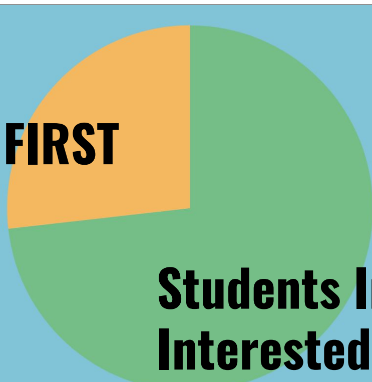
Interest and Event Feedback

82% Students interested in joined FIRST after participating in one of our events

558 Students introduced to FIRST who confirmed they are joining FIRST programs next year

4 Countries from around the world (US, India, South Korea, Romania)

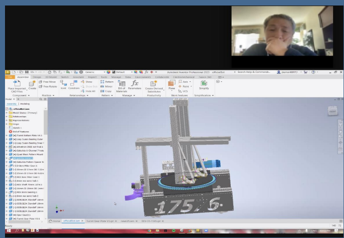
10 FIRST teams mentored, from FLL Explore, FLL, and FTC.



STUDENTS INTERESTED IN FIRST AFTER TWO OF OUR EVENTS

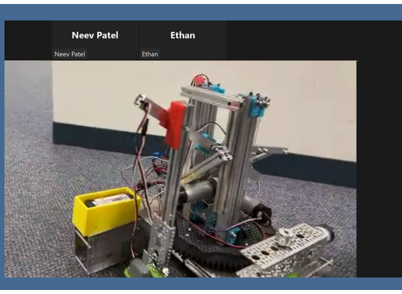
CONNECTING WITH PROFESSIONALS & TEAMS

Connected with 59 professionals across 6 organizations. More details in our notebook.



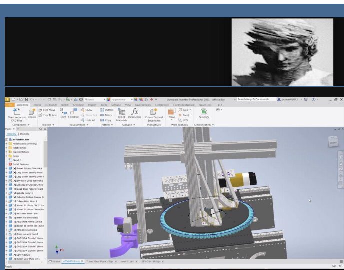
MR. CHEN (ARGONNE NATIONAL LABS): Virtual

Mr. Chen from Argonne Labs asked about encoder and vision sensing equipment and robot functionality with regards to scoring on the junctions.



MR. DOAK (GOBILDA): Virtual

Mr. Doak from GoBilda who suggested that we use different tubing for lift wiring and remove the redundant gears and limit switches on the turret; information that could easily be collected by the motor encoders.



MR. PATEL(UIUC), MR. ZHANG (CORNELL), MR. YI (DUKE), MR. GRAY (UTAH SCHOOL): Virtual

Our collegiate mentors helped us with configuring the robot to Java, OpenCV for Camera Vision, and Roadrunner for Drivetrain Programming.

IMSA Illinois Mathematics and Science Academy

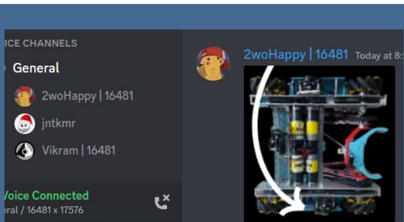
MR. SCHREIBER: IMSA

Mr. Schreiber, who has experience in FRC robot design and building, assisted us in engineering our robot mechanisms for the game tasks.

IMSA Illinois Mathematics and Science Academy

MR. PACOUREK: IMSA

Mr. Pacourek, who is a a UIUC Student with robotics experience, worked with us in designing and building the robot.



FRC TITANS #2022: IMSA

The FRC TITANS #2022 worked with us on physically building a robot off of the CAD design and using a CNC and 3d-Printer for various iterations of the robot.

MOTIVATING THE NEXT GENERATION

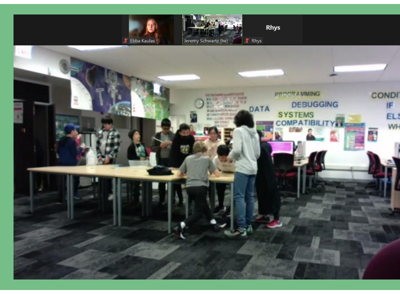
Reached 6k+ people by demos, workshops, mentoring, & social media. More detail in notebook.

ELEMENTARY STEM PRESENTATION: Evanston, IL

We presented to a total of 330 students at an elementary school in Evanston, IL.

UCHICAGO FLL TEAMS: Chicago, IL

We **mentored 7 UChicago FLL teams** virtually, in which we gave them feedback on their judging presentations and what to expect at their regional competition.



PREVIEW DAY: Aurora, IL

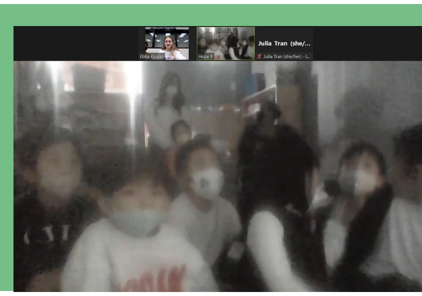
We had a booth at IMSA's preview day for new applicants. We got to meet over 200 applicants and their families and talk about our team and the program.

UCHICAGO REGIONALS: Chicago, IL

We judged an FLL Regional competition held at UChicago Lab Schools as representatives of FTC. A total of 16 different teams attended the competition

WORKSHOPS

We hosted 2 workshops (CAD + software) at the Eola Library in Aurora, as well as meeting with a primary school class in Daegu, South Korea.



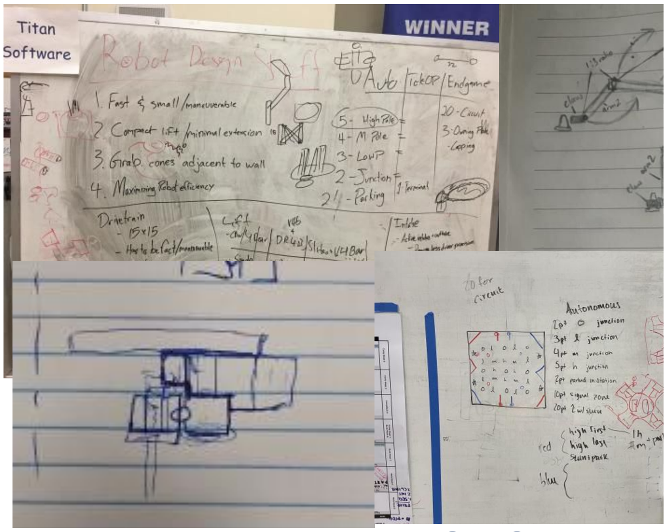
OUTREACH MASTER LIST

CONNECT Event	Organization	Location	# of Mentors	Total Hours
Design Review - Mr. Chen	Argonne National Laboratories	Virtual	1	3
Parts Review - Mr. Doak	GoBilda	Virtual	1	3
Mentorship - Mr. Patel	University of Illinois - Urbana Champaign	Virtual	1	5
Mentorship - Mr. Zhang	Cornell University	Virtual	1	5
Mentorship - Mr. Yi	Duke University	Virtual	1	5
Mentorship - Mr. Grey	Neumont School of Computer Science	Virtual	1	5
Mentorship - Mr. Schreiber	IMSA FRC	IMSA	1	21
CAD Assistance - Grayson Pacourek	IMSA FRC	IMSA	1	
Mentorship - FRC TITANS #2022	IMSA FRC	IMSA	51	32
Caterpillar Trimble Presentation - In Progress	Caterpillar/Trimble	Virtual (U.S., NZ, IN)	~40	5
Molex Presentation - In Progress	Molex	Virtual	~40	1
Total			**59**	**85**

MOTIVATE Event	Organization	Location	# of People Reached	# of People Newly Interested in FIRST	Total Hours
Virtual summer STEM WS	IMSA	Aurora, IL	25	15	40
Eola Library WS	Aurora Public Libraries	Aurora, IL	9	3	3
Barrington High School	Barrington FTC	Barrington, IL	8	N/A	2
Eola Library	Aurora Public Libraries	Aurora, IL	2	2	3
Club fair + GA	IMSA	IMSA	431	137	12
IMSA FTC + FRC season wrap up	IMSA	IMSA	30	8	5
Admissions Newsletter	IMSA	USA	4176	N/A	4
IMSA Admissions Meeting	IMSA	Aurora, IL	5	5	2
UChicago Lab FLL Mentor Session (7 Teams)	UChicago	Chicago, IL	70	N/A	4
Judging FLL Regionals	UChicago	Chicago, IL	150	N/A	12
IMSA Preview Day Brochure	IMSA	IMSA	200	N/A	3
Twitter Engagement	N/A	IMSA	174	N/A	3
Youtube Videos	N/A	IMSA	99	N/A	10
Instagram Engagement	N/A	Instagram	398	N/A	3
IMSA Preview Day / Tours	IMSA	Aurora, IL	200	186	15
Orrington STEM/FTC	School District 65	Evanston, IL	330	197	24
RoboRacers Mentorship	N/A	Virtual	10	N/A	5
South Korea Primary School Presentation	N/A	Daegu, South Korea	15	5	3
Total:			**6332**	**558**	**153**

ENGINEERING PROCESS

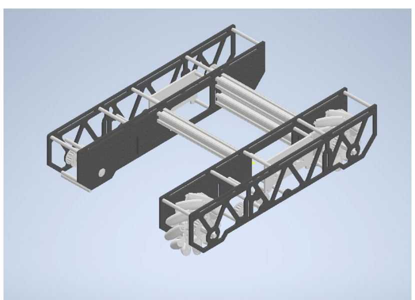
BRAINSTORMING



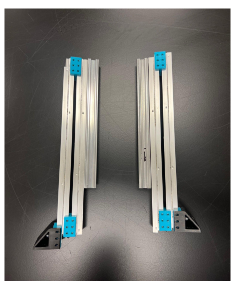
PUGH Matrix (Weighted Decision Matrix)

Design Constraints	Turret Bot	Standard Lift
Weight	4	2
Durability	3	4
Efficiency	5	3
Ease of Maintenance	3	4
Cost	4	3
Complexity of Build	3	2
Reliability	5	3
Scores	25	20

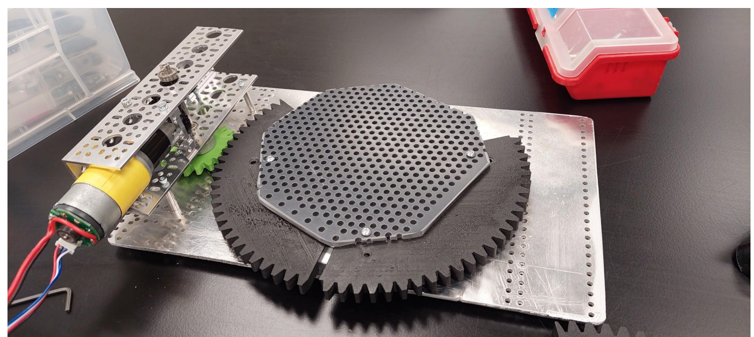
PROTOTYPING & DESIGNING



CAD of a drivetrain

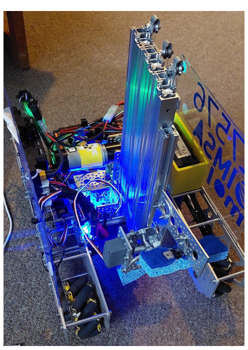


Testing new slide inserts



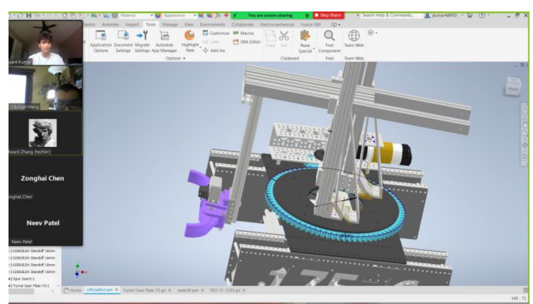
Initial Turret Prototype/Design

TESTING



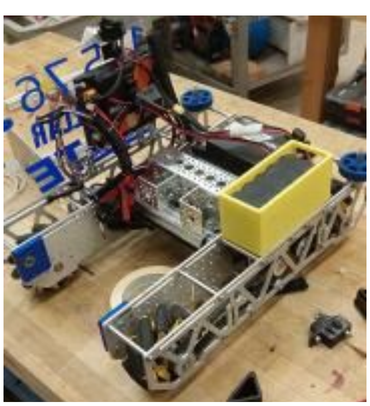
Testing of V1 Lift

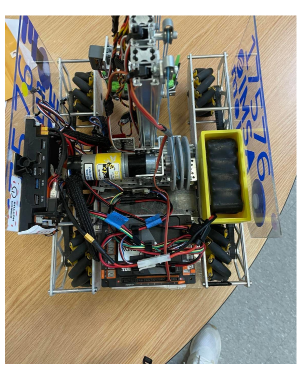
Testing of V2 Lift



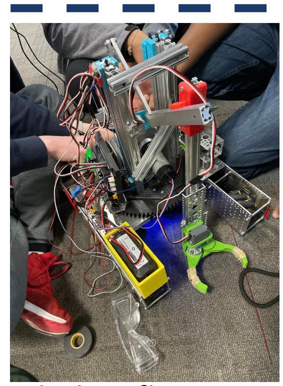
Gathering critique of redesign

BUILDING & ITERATING





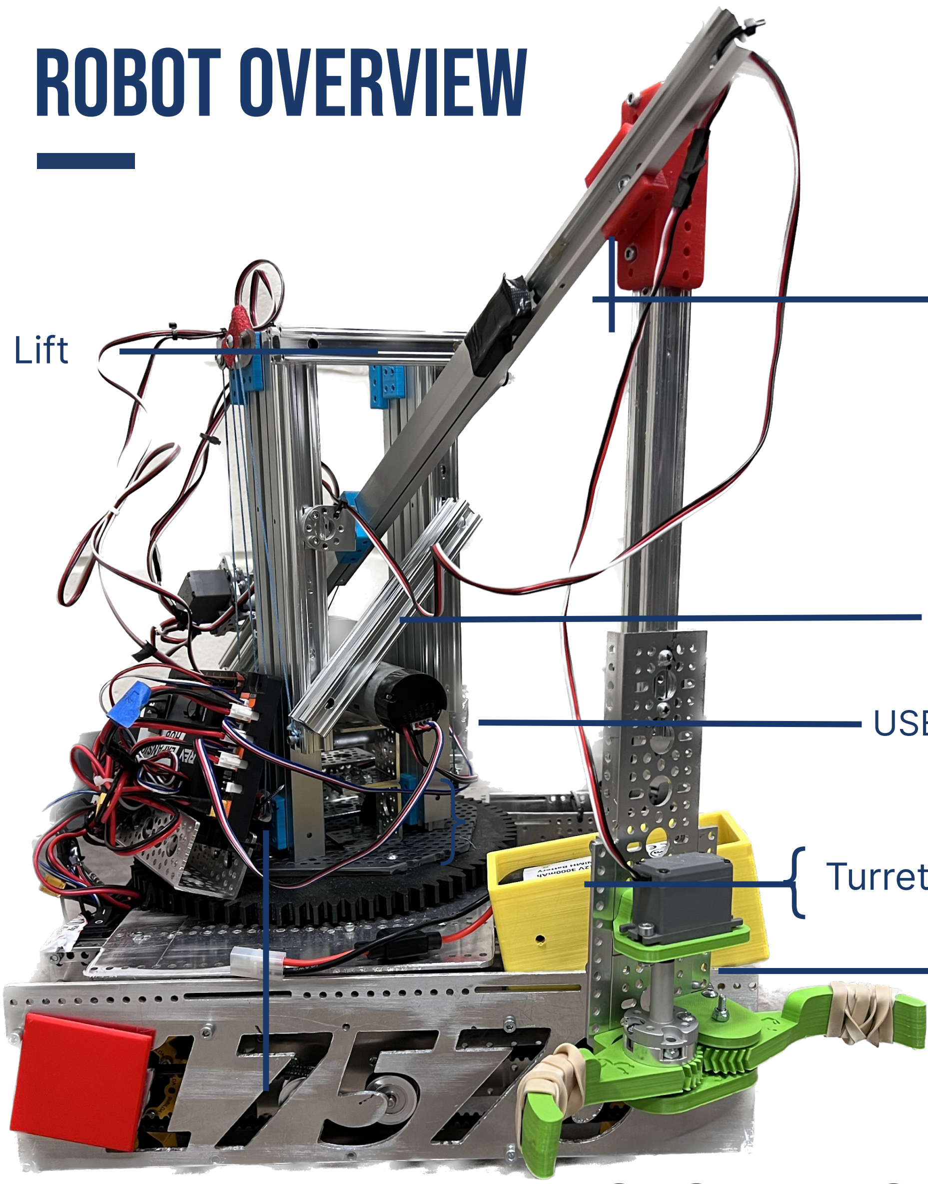
Building Meet 1 and Meet 2 robot, implementing changes based on results



Building final robot

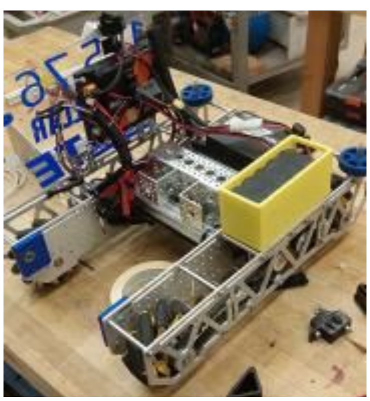
REPEAT

ROBOT OVERVIEW



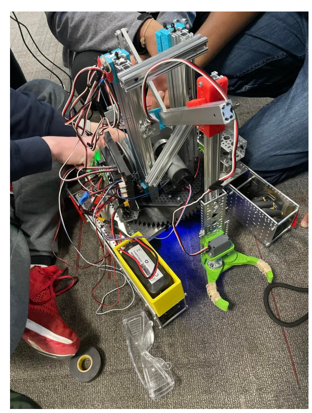
ROBOT VERSIONS

V1



CAPABILITIES	V1	V2
High Junction: Mid Junction: Low Junction=: Cycling:	4 3 3 No	7 5 6 Yes

V2



GAME STRATEGY

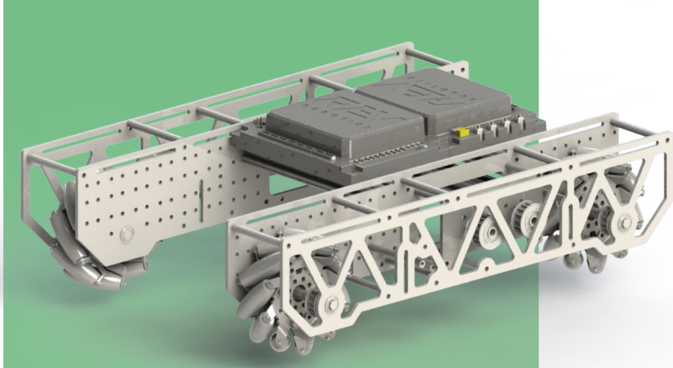
AUTO
Read barcode and park in correct position
Place preloaded cone onto high-junction

TELEOP
Cycle five stack cones to high-junctions
Deposit human-player's cones on low/mid junctions for control

ENDGAME
Finish last cycle of cones
Place beacon onto closest non-controlled junction

DRIVETRAIN

GOAL: Create a stable and nimble platform for subsystems



V1

Version 1 of our drivetrain used a 11×15 inch **mecanum drive powered by 4 19.2 Gobilda motors. Each side was geared to the central axle and belted to each wheel,** which gave it **fast turning and speed**. The drivetrain was nimble, however it was far too narrow to allow for a large claw. This made it difficult to position the robot's claw in front of cones.

Improvements using Professional Advice

- **Mr. Schreiber:** Included mounting brackets on the chassis to simplify building.
- **Mr. Pacourek:** Added a GoBilda hole pattern to the inner plates of the drivetrain, allowing for adaptability if a subsystem needs to be changed.
- **FRC TITANS:** Lowered drivetrain and flattened ends of drivetrain

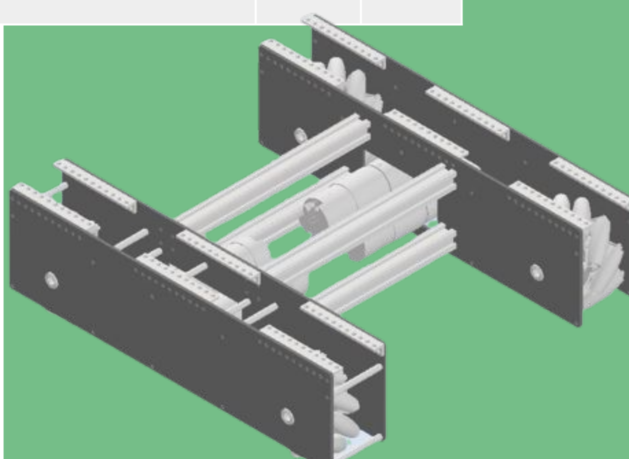
Calculations for optimal gear ratio

19.2 motor	13.7 motor
312 rpm ≈ 32 rad/sec	435 rpm ≈ 45.5 rad/sec
24.3 kg cm = 2.38 N/m	18.7 kg cm = 1.8 N/m

Thus, the linear acceleration of the 19.2 motors is 2.38*0.096/0.0009 = 253.8 m/s^2 and 192.7 m/s^2 for the 13.7 motors. Looking at the force induced by each wheel, we added $F_{friction}$ = 13N and found F_{net} = 87N using 19.2 motors and 62N for a 13.7 motor. Because of our robots short sprints, we found 19.2 motors to be better.

V2

CAPABILITIES	V1	V2
Navigate between junctions	Yes	Yes Yes
Mount horiz. claw:	No	Yes
Easy Maintenance:	Yes	Yes
Push away fallen cones	No	Yes



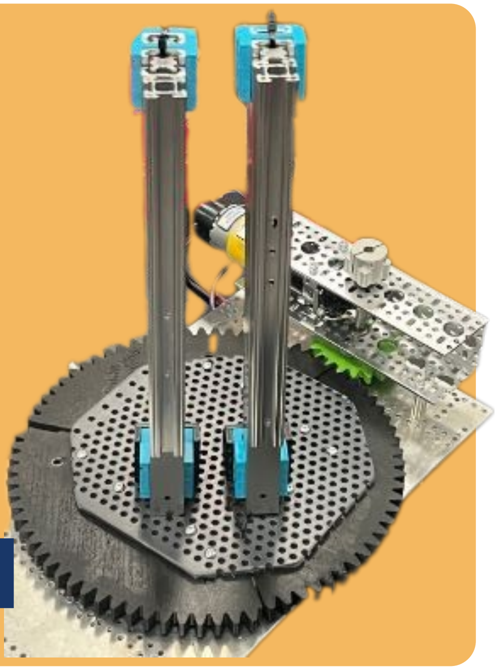
We switched to a 15×15" drivetrain to create more space for larger subsystems. We custom machined our drivetrain plates out of 6061 aluminum. We CNCed the plates for the first time on our own ShopBot CNC. We used mecanums for omni-directional movement. Each wheel is powered and belted by a 19.2 Gobilda motor.The x-rails are mounted lower, allowing one control hub to be mounted on the x-rails and directly beneath turret.

TURRET

GOAL: Increase mobility and ease of depositing cones

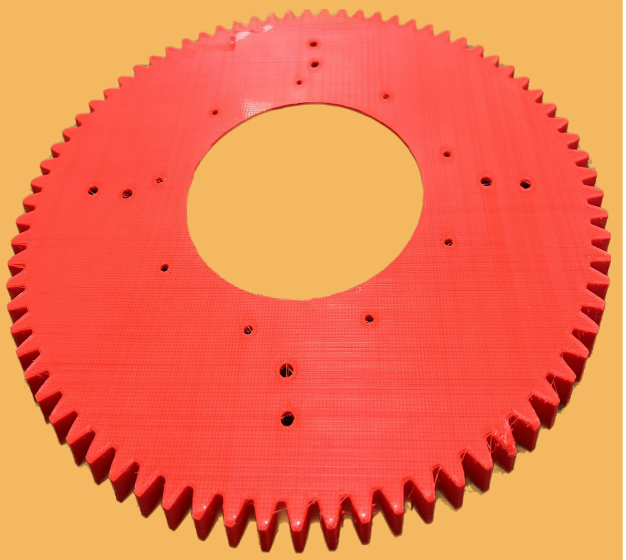
Improvements using Professional Advice

- **Mr. Schreiber:** Mounting large gear onto the lazy susan with a large o-ring separating the two. Also advised us to use a 40:1 gear ratio.
- **Mr. Doak:** Use a patterned mounting plate on top of the gear to provide rigid support for the lift and other mechanisms


V1

Version 1 of our turret used a 435 rpm motor, paired with a 40:1 gear ratio. The gears were 3D Printed. Version 1's larger spur gear had to be printed in three sections, due to its size being too large for our 3D printer. This caused inconsistencies in turning, and prevented the turret from turning past the point where the three parts of the gear met.

We gained access to a larger 3D printer and printed the entire gear in one piece. This added far more rigidity to the turret. We also added more mounting points to fix the gear onto the lazy susan underneath it, making it more stable.

V2


Calculations with the Turret Gear

19.2 motor	13.7 motor
312 rpm ≈ 32 rad/sec	435 rpm ≈ 45.5 rad/sec
24.3 kg cm = 2.38 N/m	18.7 kg cm = 1.8 N/m

The ratios between the circumference of the turret gear and the input gear connected to the motor is 7.92/2.4 = 3.3. So, the rpm on the output gear is 312/3.3 ≈ 94.55 rpm, which is more than enough for our purposes. The motor encoders on the input gear are utilized to track the position of the turret. The moment of inertia is small enough for the 19.2 motors to have enough torque to spin the turret, since the lift mechanism is placed in the center.

LIFT

GOAL: Accurately deliver the cones to the different level junctions, requiring minimal driver input

Version 1 of our lift consisted of two sets of 2 stage vertical linear slides. The misumi slides were connected to each other using x-rails, which greatly increased the slop in movement and weight. However, it was able to function properly, but was slow and inefficient.

Based on feedback from the **FRC TITANS #2022,** Version 2 of our lift replaced the intermediate x-rails with custom 3D-printed inserts. This drastically reduced the weight, allowing the lift to cycle quickly. In addition, we developed a mounting bracket to attach the lift to the turret plate. The bracket significantly increased the stability of the lift

CAPABILITIES	V1	V2	V3
Cones Scored	3	5	7

Based on feedback from GoBilda's **Mr. Ethan Doak,** Version 3 of our lift incorporated an angled bracket to mount diagonal linear slides for horizontal reach. This way, we can cycle directly from the 5-stack on the field without moving the drivetrain. The diagonal linear slides are powered by a torque servo, pushing the linear slides forward through a linkage

CLAW

GOAL: Consistently pick up/deposit cones with minimal driver effort

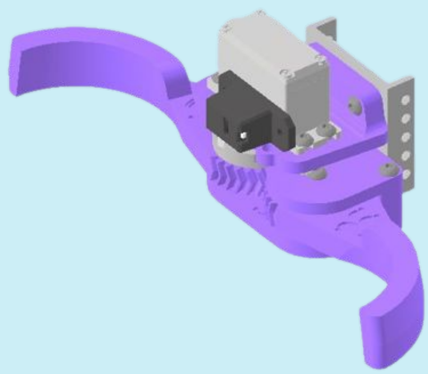
V1

V2

CAPABILITIES	V1	V2	V3
Cones Scored	3	5	7

Our version 1 claw was a top-down claw, that used a combination of sponge and rubber material to grab the cone. This proved to be inconsistent, so we experimented with horizontal claws like V2.

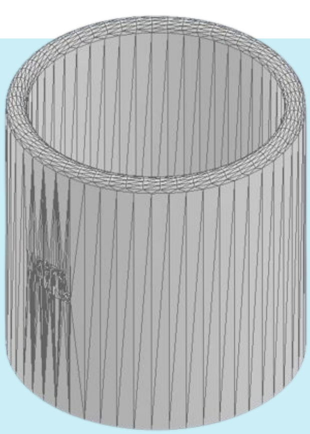
Our version 3 claw was inspired by the open-source Loony Claw, by the Loony Squad. Having one-servo close and open both arms made it have a much larger area to grab onto the cone. Modifications were made for mounting and catering to our specific needs, like changing gear ratio for more grip/torque.



V3

TEAM BEACON

GOAL: A simple beacon that requires very little instruction for the human player

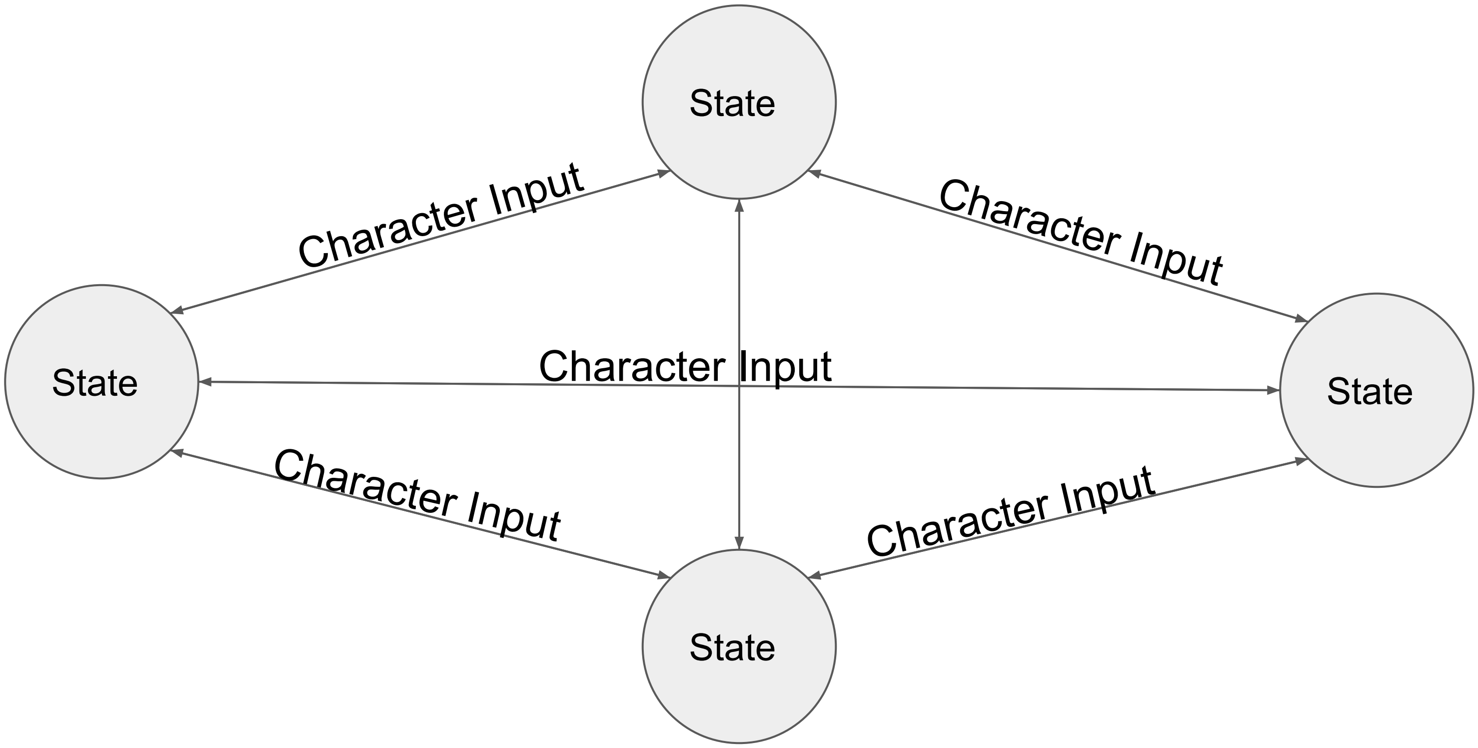


V1

Our Team Beacon was designed for ease of use. Knowing that human players from alliance teams will need to handle our beacon, we made it as simple as possible. The beacon is the same diameter as a cone, allowing for the same mechanism to pick up and deposit it onto the junctions.

SOFTWARE

- We've developed virtual finite-state machines for better tracking and implementation of motion control
- Our teleop implementation is based on creating an enhanced driver experience to reduce friction (See Driver Enhancements).
- During autonomous we've focused on increased scoring and functionality by implementing repeating update loops for the virtual finite-state machines to allow for near instantaneous update without impacting drivetrain performance

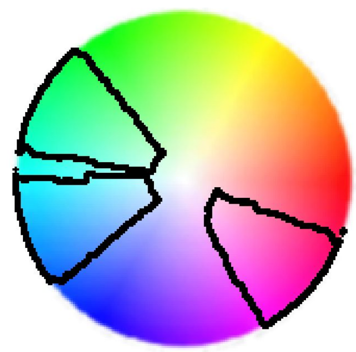


DRIVER ENHANCEMENTS

- We planned a automation assisted driver controls scheme where repetitive motions were fully completed with a single input
- After implementing a typical two joystick mechinum control scheme we encountered difficulties with speed control
    - To fix this we removed encoder functionality from drive motors to allow proper speed control

CAMERA VISION

- OpenCV
  - OpenCV is an open-source library for real-time computer vision. Our team uses EasyOpenCV, an adaptation for FTC.
  - We developed a custom pipeline to detect our game element.



EasyOpenCVSim - HSV Color Wheel

OpenCV

- **Custom pipeline**
  - **Image is blurred with Gaussian Blur for easier contour detection**
  - **Camera data is converted from RGB to HSV**
  - **Draws contours around the groups of pixels in the correct HSV ranges**
  - **Identifies the biggest contour and draws a bounding box around it**
  - **Returns the color/required parking position**

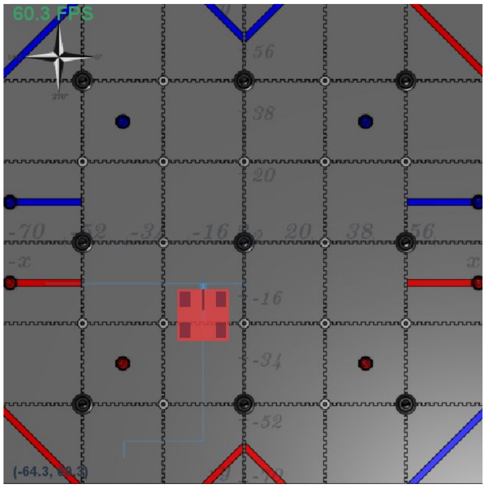
EasyOpenCVSim

- **Allows testing of custom pipelines on computers**
  - **Easier testing without a robot**
- **A HSV wheel is used to test camera color ranges**

ROBOT MOTION

> **Our robot paths are first planned using MeepMeep, a path visualization tool**
  - **We are able to see the time our paths takes to make sure they fall within the 30-sec requirement.**

> **Our paths then use Roadrunner, a motion planning library**
  - **Using drive encoders, we are able to know the position of the robot at times**



Path Visualization