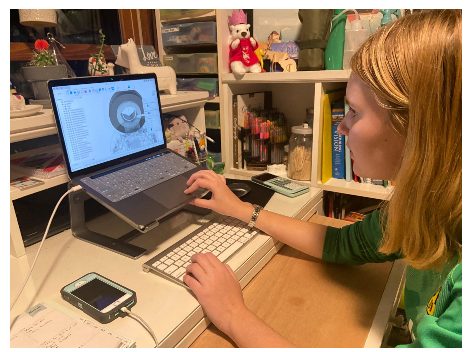
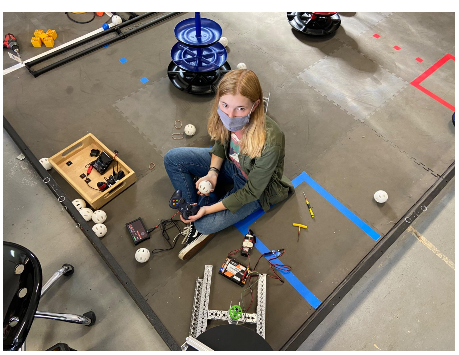
Freight Frenzy Engineering Portfolio 2021/2022

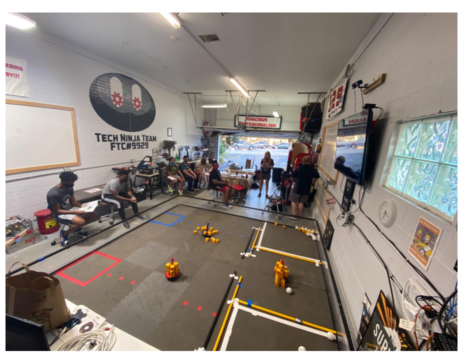
Team Overview

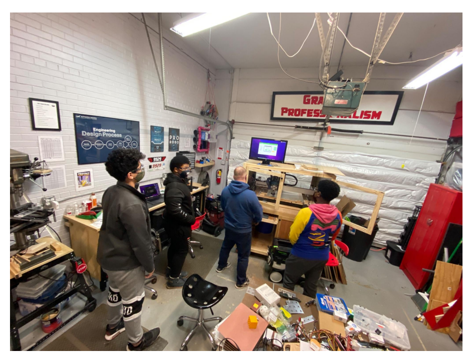
We are the Tech Ninja Team, a community team from the Homewood-Flossmoor area. This is our team's 7th season, but many of us are new to the team. We are all veterans of the FLL teams that met on the other side of the garage from our workshop and decided to continue with FTC. Our team has 7 people, ranging from 7th graders to juniors in highschool. And we have all made great friends with each other. So we have come far as a team and are working hard to be great.

Being a ninja is about upholding our values: acting now - and iterating, communicating effectively, expecting and embracing change, and taking risks without panicking. With our team being smaller, and less experienced overall than last year, it has caused us to really live up to our values, and stretch ourselves in new directions.





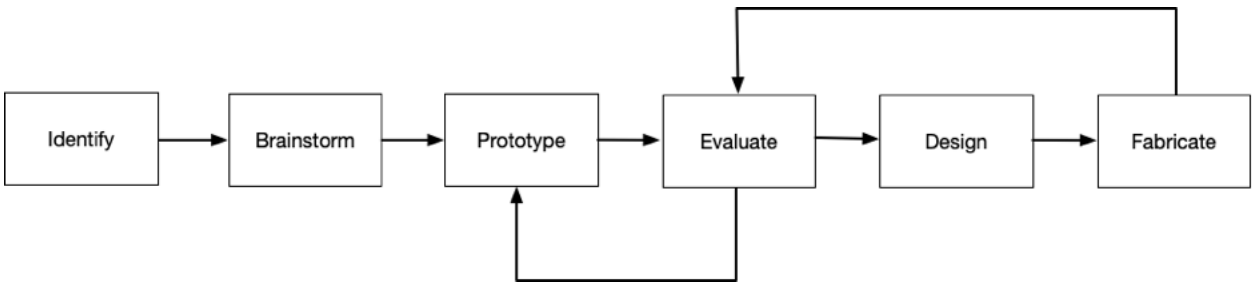




How We Work

Like many FTC teams, we have a build team, a software and controls team and drive teams. Team members choose a sub-team specialization based on their interests and skills, but sometimes because of need or particular interest they may work on parts of the robot that are not their “usual” team.

We follow this engineering design process:



- Identify – identify the problem to be solved
- Brainstorm – brainstorm solutions
- Prototype – quickly build physical or mathematical models to evaluate the brainstormed solutions
- Evaluate – run experiments to see if the solution works
- Design – design a solution to use on the robot based on the prototype(s) and the evaluation
- Fabricate – machine, assemble or program the solution that was designed. Evaluate whether it meets the requirement.

Strategy for Freight Frenzy

We met during kick-off weekend, watched the reveal video, and then set to work learning the rules of the game so that we could come up with a strategy for playing it. We could maximize our time spent working on the mechanisms that would let us obtain the most points in matches. We found out the ways of scoring in this year’s game that were “red herrings” or “time wasters”.

One such example is delivering the team scoring element from the carousel for 6 points, rather than using the barcode in auto, and getting 20 points. Our team shipping element would be on the field in both cases, but we would earn 14 points more for using it in auto rather than delivering it. This told us we needed to focus our attention on using the team shipping element on the barcode, which led us to make certain decisions about our mechanisms and code.

We then created documentation for each mechanism describing relevant game rules, desired qualities for the mechanisms, and other constraints. This documentation served as a reference for the entire season. It helped us evaluate our prototypes and mechanisms and make sure we were on the right track and moving in the right direction while we iterated upon our robot.

The strategy decisions we made at the beginning of the season had major effects on the mechanical design and software of the robot this season.

Robot Design and Fabrication for Freight Frenzy

Identify

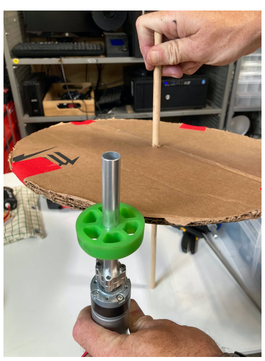
The first challenge with the carousel mechanism was figuring out the constraints. During our robot build weekend directly after the game's launch, the whole team discussed what the carousel mechanism needed to do and our ideal constraints for the mechanism to complete its job most effectively as well as the maximum amount of points that this mechanism could possibly obtain in order to determine how much time we needed to spend on it. Here is what we came up with:

Possible Points (delivery only):	Desirable Qualities:	Constraints / Component Budget:
● 10 during auto ● 54 during end game ● Total - 64	● ≤ "duck flight" speed ● Ambidextrous ● Duck does not fall on robot ● Duck falls near intake ● Delivers all ducks during end game	● 12.5" high ● Only touches rim of carousel ● Fits in 18"x18" box

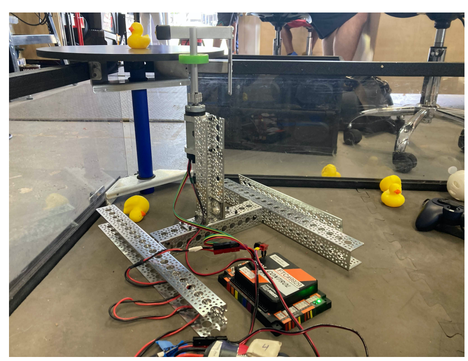
Brainstorm

The team decided that the best option to reach our desired goals would be to keep a simple design rather than a complicated structure that could be prone to failure. Most of the ideas that were discussed included a wheel that would spin the carousel. We discussed using different types of wheels, different configurations, and different ways to drive the wheel. We decided to explore a few options in the prototype stage, but all a fairly similar design.

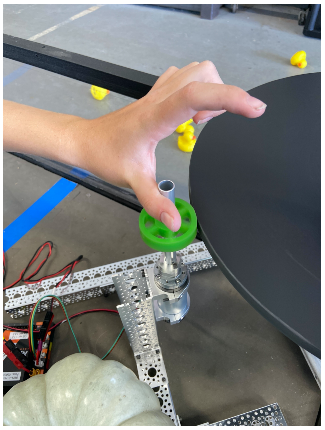
Prototype



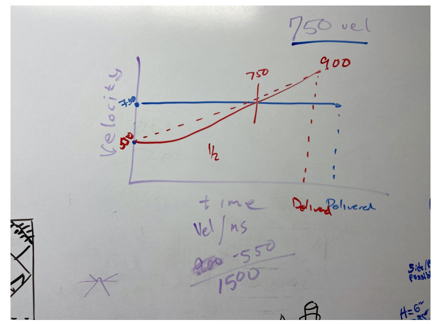
We immediately ran into an issue while prototyping. We wanted to score the most points possible so we figured we would need to deliver the 9 remaining ducks in 10 seconds during the end game. Since the circumference of the carousel is about 48 inches, we figured we would need it to move about 48 in/sec to reach our goal. If we used a 2 inch compliant wheel, we would need a motor or servo with 8 revs/sec in order to deliver all 9 ducks within endgame and give us ample time for other end game activities. There is no available servo that meets that speed so we could go with a larger wheel/roller or a motor. We decided to continue prototyping with a motor since a large wheel would take up more space and a motor, while also bigger and heavier than a servo, would be easier to find space for.



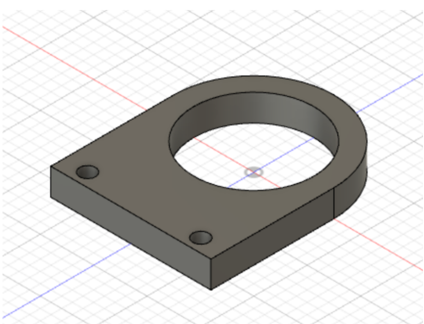
Evaluate



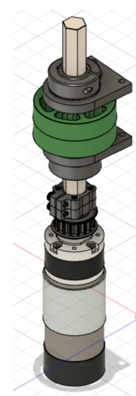
While prototyping we discovered that the compliant wheel and motor combination worked very well. We ran into some issues with the speed and placement of the duck. In order for a velocity to be reliable it had to consistently deliver the duck without flinging it off the carousel (aka duck flight). We found that there was a major difference in reliable velocities depending on where the duck was placed on the mechanism. When the duck was placed more toward the center, it was reliably delivered with a faster velocity (about 750 enc/sec) than if it was placed towards the rim of the carousel (reliably delivered at about 500 enc/sec). We tested to find these values using a neverest 3.7 motor. We decided to use a slower speed during the autonomous period because we do not control the placement of the ducks then, but use the faster speed during endgame where time is a constraint and we have control over where the ducks are placed. We decided to add a velocity curve to aid in smooth delivery in both auto and endgame, which allowed us to deliver faster than a constant velocity as well. We also discovered that when the mechanism had less axle deflection, delivery was smoother and more predictable. This was important to know because it added another constraint to our final mechanism, it had to be rigid to allow for smooth delivery.



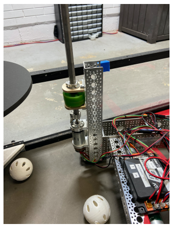
Design



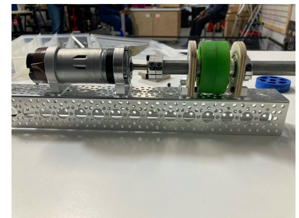
Once we decided what our mechanism needed to look like, it was time to design it for real. We decided we would need custom parts to hold the bearings for the compliant wheel structure. We designed a version in CAD. We used a motor mount pattern to decide where to put the hole for the bearing. We then used a hole pattern to determine where to drill the holes for the screws so we could use a screw block to attach it to a piece of channel that would be fixed onto the robot. We then constructed a stack of axles, clamping hubs, bearings, and spacers to make our mechanism a reality. We also added another stack of wheels to the other side of the robot connected to the original mechanism using a timing belt. This would allow the drive team to be in the optimal position for delivery on both alliance carousels without using another motor.



Fabricate

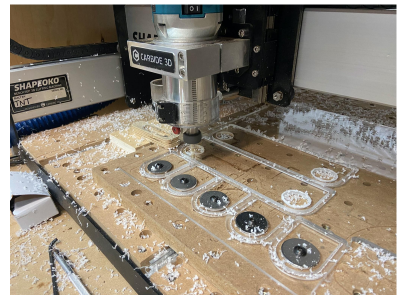


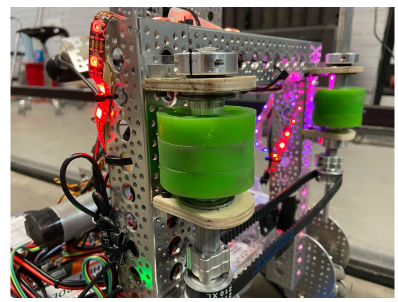
We fabricated the first iteration of the bearing mounts out of wood. We cut the wood on the bandsaw. We then sanded. We located and drilled holes for the screws in the exact spots they needed to be to fit the screw blocks. This went pretty smoothly but it was not as exact as we wanted, but it worked for the moment.The code was implemented with the velocity curve and the mechanism was mounted on the robot.



Implement (cont'd journey)

We knew we wanted to cut our next iteration of the bearing brackets on the CNC because it would be more accurate than fabricating it by hand. We got to work on creating the new and improved version. Our second version had mounting holes in the side that we tapped so the could be attached directly to either a new side plate or channel. We never got to test how effective this was, but it was really cool to go through the fabrication process and learn how to use the CNC from the CAD work necessary to actually running the machine. We also added another wheel to the wheel stack. This created more of a roller and increased the chance that we would have full contact with the side of the carousel even if there was some variation of height on different fields as allowed by the game rules.





Freight Manipulator Design and Evolution

Identify

It was obvious we needed a way to pick up and deliver freight, the main game pieces this season. Since this mechanism is a main part of the game this year, we developed relatively strict constraints for it.

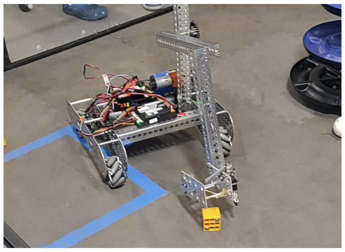
Possible Points (delivery only):	Desirable Qualities:	Constraints / Component Budget:
• Autonomous: 10-20 • Tele-op: 2,4,6 points	• Can intake one item at a time • Can intake all given items (Ball, cube, duck). • Intake one second per freight • Ability to pick up items pushed up against the wall	• Must fit within the 18 inches constraint • Has to be able to reach, 3 inches, 18.5 inches, 14 3/4

Brainstorm

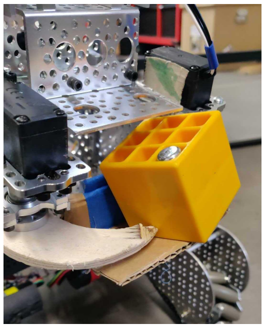
We wanted to have a mechanism that would be easily controlled, while also having the ability to reach all levels of the drop offs to get as many points as possible. We could build an L-Shaped arm that could be raised 180 degrees, however with the size of the arm and constraints needed for it to work, we could not use the 180 degree lifting arm. We wanted to use that design because our robot would not need to turn around in order to deliver an item after picking it up. Instead we decided to not use the L-Shape and have it only raise enough to reach the 3rd level of the drop off

Prototype

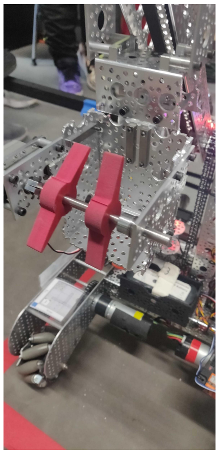
First we started with an L-Shaped arm that would hold the intake mechanism and would be able to be easily lifted up and down. We went with a few prototypes, like this prototype to the right featuring a grid of surgical typing that could hold freight being picked up. We also tried a door with a wooden box and a servo to open and close.



Evaluate



We eventually went with a wooden gripper with servos on both sides, to grip freight. We went with this because it had the best results when we tested all of our prototypes at the time. The gripper had some issues, which included the inability to deliver to the top level, and getting the mechanism stuck inside holes inside freight and cargo. We could also not pick up ducks. We tried solving the first issue by adding a ramp to the gripper to slide off freight, as you can see in the image to the left.



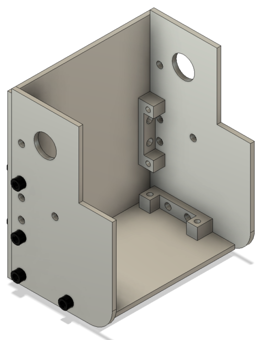
Design

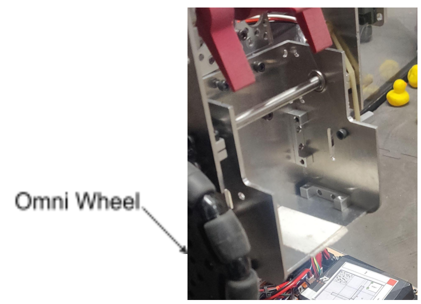
Because of the issues we ran into with the gripper mechanism, we went back to the prototyping stage and tried a few prototypes with spintakes. We decided to change the intake in this way because it is a critical part of our robot, it is practically the only way to score points in the regular driver controlled period. We spent a lot of time designing and iterating this mechanism for that reason. This design of the intake is also “spring loaded” with surgical tubing, which allows the freight to be collected and sit securely in the “ box” part of the mechanism. We also designed the final version of our mechanism to be able to reach the top stage of the shared shipping hub. This was an important iteration for us to gain points.

Fabricate

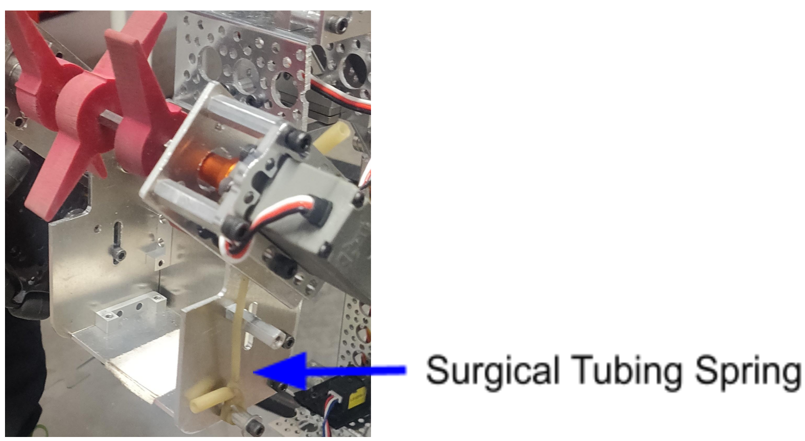
We built the prototype featured immediately above out of an Actobotics plate. Once we were happy with the dimensions and overall design, we designed parts in Fusion360 so we could cut aluminum parts on our CNC router.

The assembled intake box, designed in Fusion360, is shown below on the left. The as-assembled intake box is shown below on the right. We added a large black omni-wheel to prevent the intake from digging into the playing field while the robot is moving. In this photo, our spintake axle is rotated up and out of the way.





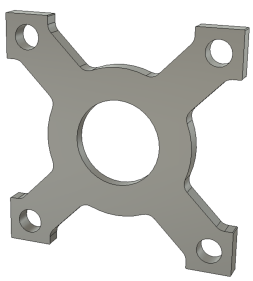
The photo below shows our spintake axle in the up position and the short piece of surgical tubing that we use as a spring. This spring is important because it allows our intake to accommodate different size pieces of freight.



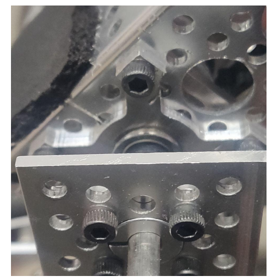
As we got the robot ready for our league tournament, we tackled some improvements to our primary arm. Our arm uses a timing belt and pulleys to act as a four-link mechanism. This ensures the intake mechanism is always facing “forward” and does not angle up or down. We initially used ¼” shafts and bearings to mount the pulleys, but the set screws on those had a tendency to come loose and allow the intake mechanism to swing.

To address this problem, we found pulleys that have a “D”-shaped bore. To use this, we had to swap our ¼” shafts for 6mm D-shafts. We did not have any bearing mounts for 6mm bearings, so we made our own bearing mounts out of sheet aluminum. The new shafts, pulleys and bearing mounts substantially reduced swinging in our intake mechanism.

New Bearing Mount Designed in Fusion360



Fabricated Mount on Robot



Drive Base Design and Evolution

Identify

Possible Points (delivery only):	Desirable Qualities:	Constraints / Component Budget:
• N/A (All points, we need a drive base to score this year)	• Traverse over warehouse bars (1.26” diameter, 4.5” apart, not losing orientation in auto) • Fit through warehouse bar gap (12” width)	• Fit 18” x 18” sizing box

Brainstorm

We realized that we had a similar challenge of climbing over a low obstacle on the field with Rover Ruckus a few seasons ago. We figured we could use our experience from that season to help us prototype this year’s drive base.

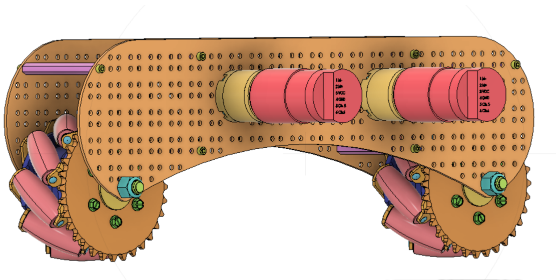
Prototype

We happened to still have the side plates for the drive base from our Rover Ruckus season, so we decided to rebuild that base and see how it would fare against the warehouse bars.

Evaluate

The existing base worked surprisingly well, so we decided to keep the general design of curved side plates. These curved plates allow the robot to move over the bars without getting caught. They also have a unique shape that allows us to stand out, which is a plus too. One drawback of using the existing base is that it ended up being wider than the 12” gap between the warehouse bars and the playing field wall. Having a larger robot means we cannot bypass the bars or score in the shared alliance hub easily. However, we did not see this as a huge issue because we could easily go over the bars and we favored the robustness of a large drive base over the ease of getting to the shared shipping hub.

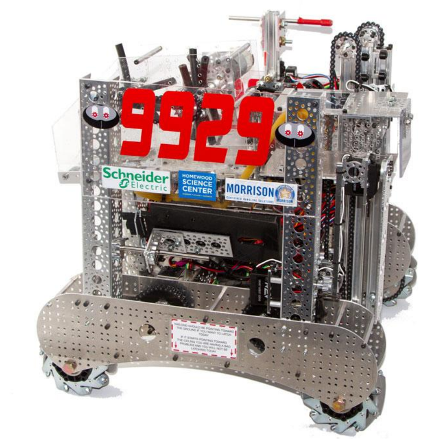
Design



Creating the design for the drive base was a pretty quick and easy process. We used the plates that we already manufactured from Rover Ruckus. This saved on time and material while also being effective in achieving most of the goals we had for the drive base.

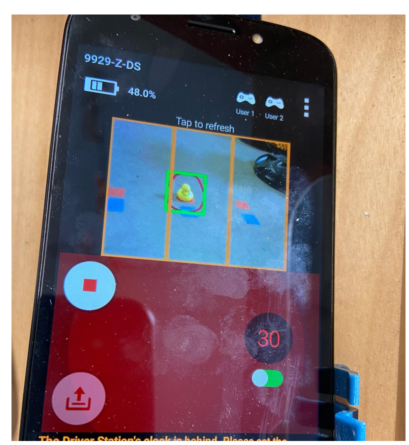
Fabricate

Very little fabrication was necessary for the drive base considering it was re-used from a prior season. All we had to do was put it back together and mount mechanisms on it to make the full robot.



Software for Freight Frenzy

Barcode Detection



Our vision system is built as an OpenCV pipeline and used in the autonomous period to detect the barcode position. The software team designed the system using GRIP. GRIP made it possible for the team to build the barcode detector before we had a robot as well as let everyone on the software team participate in building it, because we could run it on a laptop and share it via Zoom while we were prototyping. Our detector is capable of detecting the barcode in under 500ms. It does this by detecting areas of yellow and computing the center of the bounding box of the yellow area. We chose yellow because it is the color of the duck and it is easier to point out on the field. The center point is then located in one of three zones of the camera’s view, each representing a position on the barcode, left, center, or right.

Sensors

- Encoders are used to keep track of the position of the motors. They work by keeping how many rotations a motor has spun, and we can use the diameter of whatever is attached to it to figure out how much it has spun. All of our motors have encoders, which makes it easier to keep track of positions inside the software.
- There is a distance sensor on the back of the robot to help correct the robot’s position when parking in storage during auto. The sensor measures the distance between the robot and the wall, and then makes adjustments if the robot is not parked completely inside the storage unit.
- There is a limit switch on the robot to help the robot know when the arm is at the lowest position. When we press the buttons to go to certain positions, we have to know where the arm is and its lowest position.
- We also have LEDs on top of the robot to help signal the drive team about what phases are going on and what the robot is doing. We have alliance colors when setting up for auto, and when detecting the team scoring element was a success. We also have different color codes for when tele-op starts, when to go to the carousel to get ready for endgame, and when to drive to the warehouse before endgame ends. We have this to help the drive team know what time it is while driving, since it is easy to lose track of time. Since everyone is focused mainly on the robot during the match, we found it easy to have a way to signal the drive team without looking for the match timer.

State machines

Our team utilizes state machines in both autonomous and tele-op. We use them because they allow us to automate a series of tasks, which are broken into states.

The state machines used in tele-op also allow switching between complete driver control (open loop) to automated assistance (closed loop) for mechanisms that require multiple steps to operate. This automation allows us to streamline a set of multiple, repetitive tasks to one button, or prevent errors if the human operators were to ask for things to happen at the wrong time or in the wrong order.

An example of such a set of tasks this season is moving the freight manipulator arm to the low, mid and high level on the shipping hub at the press of a button - code that is also reused by our autonomous code. The code also does not allow the intake to operate when the arm is moving, to prevent mistakes by the human operator.

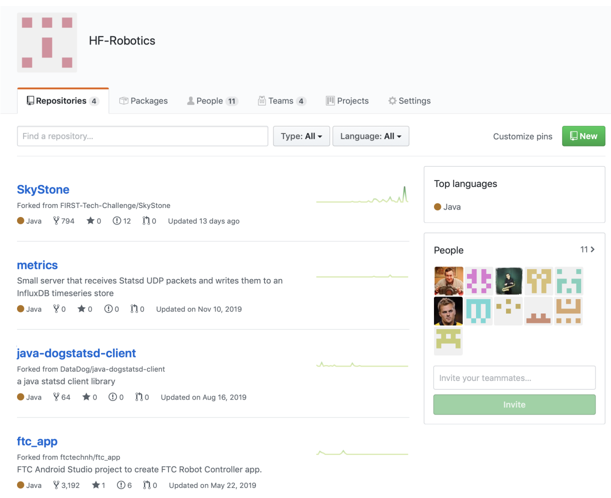
In addition to making tasks easier and safer to complete, the computer's reaction time is a lot faster than a human's. This allows us to steal back milliseconds throughout the match, which can add up to more time to allow the team to score more points.

But sometimes the sensors our code depends on break or become miscalibrated. When this happens the driver can take full control of the robot using the “unsafe” buttons, which temporarily turn off the limits and safeties we use to automate our code. This means a faulty sensor doesn’t mean that the mechanism it is attached to is inoperable (both things have happened, more than once!).

Outreach for 2021 - 2022

From the end of the Ultimate Goal season until this season started, team members helped fill STEM learning kits for the organization that hosts our workshop. Homewood Science Center passed out thousands of PopUp SCIENCE @Home hands-on learning kits to kids in our community to help keep science learning alive during the pandemic.

Young learners excited to explore PopUp SCIENCE @Home STEM activity kits.



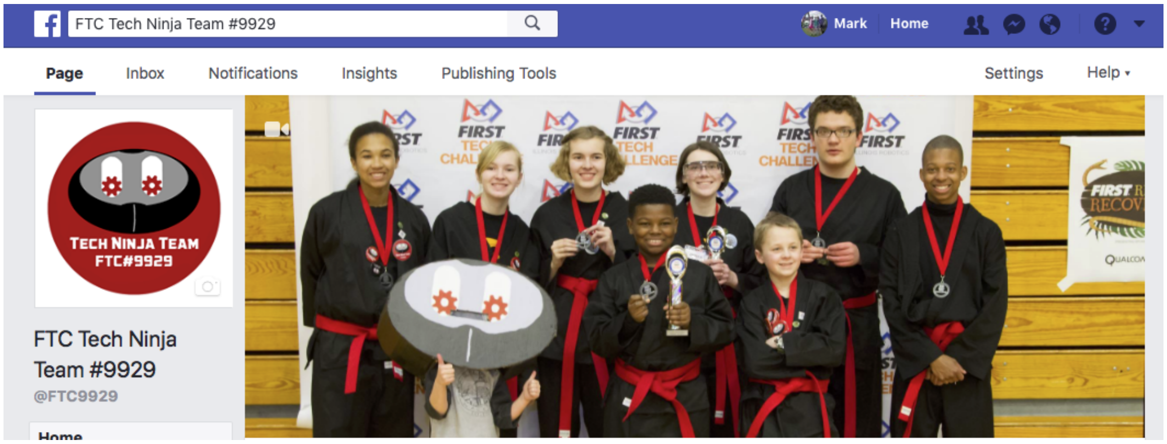
GitHub – We share all our robot code with the world as we write it on GitHub

It is also on GitHub where we publish TntFtcCore, which is a publicly available library of code available for anyone who wants to use it. It was made as a legacy project by the senior programmers. It consists of software produced over the multiple years the senior programmers have participated in FTC. This software is designed to make advanced tasks more reliable and easier to program. It already has 100+ downloads per month

Website

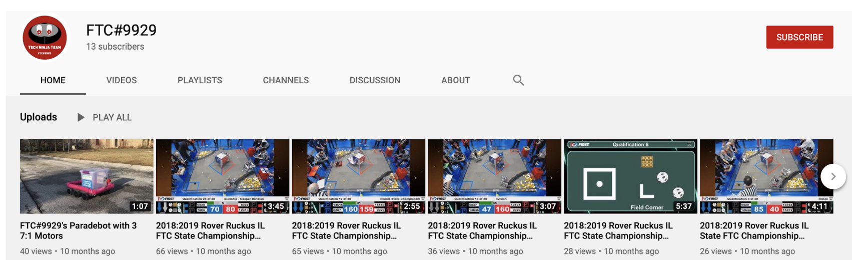
The team has its own independent website. It features pictures of events and meets, information about both the FTC FIRST program and our team, some blog entries of things we have learned, and even past seasons' Engineering Notebooks to serve as examples to new teams. We use the website to reach out to potential sponsors and the community.

Facebook – We have our own Facebook Page, used more to reach local audiences (upcoming events, news). We have 150+ followers that are primarily within the state of Illinois or are family and friends of the team members.



Twitter – We are @FTC9929 on Twitter. Here is where we tend to keep up with other FTC teams, sharing our successes (and experiments that don't quite work out). We have over 450 followers, and we enjoy seeing how teams around the world are having fun with robots and STEM.

YouTube – We have many videos including footage of previous matches and tech tips such as "Friends Don't Let Friends Use KEP Nuts"



Sustainability

This season we were fortunate to once again be awarded a grant from Schneider Electric.

We have a lot of costs that Schneider helped cover:

- Power Tools ($400)
- Robot parts and spares ($1400)
- Competition Registration ($275)
- Sanitizing supplies!

We look forward to our team's continued collaboration with Schneider Electric, and continuing our site visits and demonstrations at their offices and events where we get to talk to their engineers and technicians.

The Homewood Science Center has been invaluable to us for many seasons. They provide us with space to work and have introduced us to our sponsors. We give back by volunteering at their events, which in turn helps us with STEM outreach. The Homewood Science Center allowed us to maintain access to our shop throughout the pandemic. Being able to use the shop has been great because it allowed us to have access to our tools and have enough space for social distancing.

The Tech Ninja Team tends to recruit new members through our sister FLL teams. This year, the entire team are veterans of the FLL teams that meet next door to our workshop. Because of capacity limits due to COVID, we did not have workshop hours that overlapped, but we did leave supportive messages for each other before big competitions (the FLL team went to State!), and we upgraded the lighting in their side of the garage so they could better prepare for that.