Team 14140

Crash Test

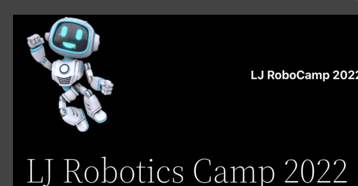
“Fun, Learning, and Friends”

The Team

A 10 Year Plan Before there was Crash Test, there was WaterWorks. Before that, there was Team TRASH, before that, there was the Green Robots. Our team has been traveling together through FIRST for 10 years! ***And this is it.*** It was always our plan to go all the way through High School and **pass the baton to others**. While we do not intend for Team 14140 to continue, it was also always our plan to have a **lasting impact on FIRST**. So while 14140 may be ending, **the positive impact we have had will go on for decades to come**.

22-23 Skills Development For the last three seasons, we've continued to develop our **CAD skills** by creating a full model of each iteration of our robot. We also added CNC and laser cutters to our skills this season. Additionally, several members took AP CS A this year to learn Java. Our massive Outreach and Connect efforts put us in touch with numerous experts who added to our knowledge of robot control, design, software, and much more.

Finances Our team is community and sponsor funded. We maintain our accounting using Wave Accounting software for Small Businesses. This season we launched RoboCamp, a summer camp experience for younger kids that helped us fund our future!



Reflection and the Future FIRST has been an incredible 10 year experience. While we have learned a ton about STEM, when we look back, we can clearly see that many of the most profound lessons were "More Than Robots". We have learned communication, leadership, networking, sales, risk management, and so much more. Perhaps most significantly, we will go forward with a solid understanding of how to tackle a hard problem, without enough time or resources, on a team of people who think differently from oneself. If we are going to solve tomorrow's problems, collaboration, out of the box thinking, and rapid iteration are going to be important. Some of our graduating members will be pursuing STEM careers and many of us plan on coming back and volunteering or mentoring within the FIRST community.

Goals, Plans and Results

Long Term (FIRST Career)

Goal	Results
Travel together from 3rd-12 grade having fun and learning.	• **We are in year 10** (our last year) 5 of 6 members are founding • We are still having a blast!
Leave FIRST funner and stronger than we found it.	• Started **over 12+ new FIRST teams, mentored 500+ kids.** • We've done **our best to model GP** at its finest and have been recognized
Inspire kids around the world to come play with robots.	• **100,000+ views** of our "How To" videos on YouTube. • Founded a **Robotics Summer Camp** that will go on for years to come. • Helped start **robotics schools in Columbia and Sri-Lanka** as part of an initiative to use STEM to help heal/progress war-torn countries.
Inspire as many professionals as we can to come help FIRST	• **20+ companies and organizations with over 100,000 employees** connected • Countless new volunteers and mentors as a result

Season Goals

Goal	Plans	Results
Connect 10+ Companies and 10,000+ employees	Identify at least 10 new prospects and and develop at least 6 of them	**12 Companies Connected with over 100,000 employees**
Drive past **100,000 views on YouTub** e while continuing to mentor locally	Continue to **monitor our comment stream**. Post **explainer video of last year's robot**. **Work with LJES** and others	**108,000+ views in 50 countries** **500+ comments, Q&As.** **LJES FLL program (5 teams) restored**
World Class Robot with **100% autonomous consistency** and **faster than needed game play**	**Identify clear game/design goals** at the start of the season. **Iterate relentlessly** to achieve them.	6 Cone Autonomous is at **98.8% consistency.** Our Teleop **performance requires us to slow down** to avoid running out of cones too soon
Our Most Innovative Robot Yet. **Unique in the world** and highly effective	**Identify 2-3 key innovations** over the course of season and iterate to success	Our swivel deployment arm and "JIT" Pole bracers are **unique as far as we know**. Secret Weapon installed
Our Most Beautiful Robot Yet, driven by **clear design principles**, balancing form and function	**Identify clear design principles** and **apply them from top to bottom**	**5 clearly defined design principles** led to a **beautiful fusion of form and function** that speaks for itself
Operate Independently of Adults	**Set our own goals, tempo, and schedule.** Rely on our coach minimally.	Goals established and reached Coach doesn't know when we meet
Finish **Helping the SD FTC Region Recover**	Focus on **hosting events wherever there are not other teams to step up**	1-Site, 4 Meets Model adopted **4 League Meets hosted this season**
Cement our Legacy, **Look to the Future**	Use Connections to **learn about what is next for us** as we leave FIRST. **Hand off ongoing camps** and mentoring responsibilities	**10 meetings with College groups and STEM professionals** to talk about "what's next". **Handing off** Local and International **Camps**

CONNECTING

Just One Coach We've only ever had a single coach so we have been reaching out to experts from the start. We have learned robotics from the best, coding and AI from a number of companies, and partnered with universities to expand FIRST and recruit more volunteers.

Please visit our pit where you can see our Connections Poster where we detail what we learned from each of our connections and also what they learned about FIRST. In most cases, this has resulted in more volunteers and support for our region and beyond.

The Intuit Project

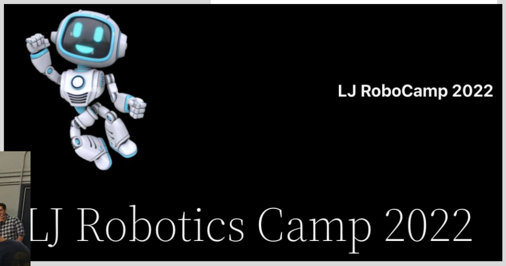
This season we have a major project underway to bring one of the World's leading software companies into the FIRST Family. We have met with representatives of Intuit's "We Care and Give Back" program with the goal of having Intuit promote volunteerism in FIRST to it's 17,000 employees world wide. A showcase is scheduled for May on the Intuit Campus in Carmel Valley where we will be generating buzz and excitement within Intuit to get involved in FIRST. This event will include not only FTC but also FLL and FRC teams to get the company wholeheartedly involved in supporting FIRST Robotics.

MOTIVATING

We **start new teams** (10+), **mentor existing ones** (5), **collaborate with others** (12+) **help start robotics camps** in war-torn countries to promote healing and peace (2), conduct **our own robotics summer camp** (3), **support our region** when no-one else can step up (4 meets, The Hub), and **promote youth robotics** wherever we can (LJAWF, etc.). **Our YouTube channel drove past our goal of 100,000+ views this season in over 50 countries.** **Please join us in our Pit for all of the details.**

Impressions
510.8K

Your channel has gotten 100,883 views so far

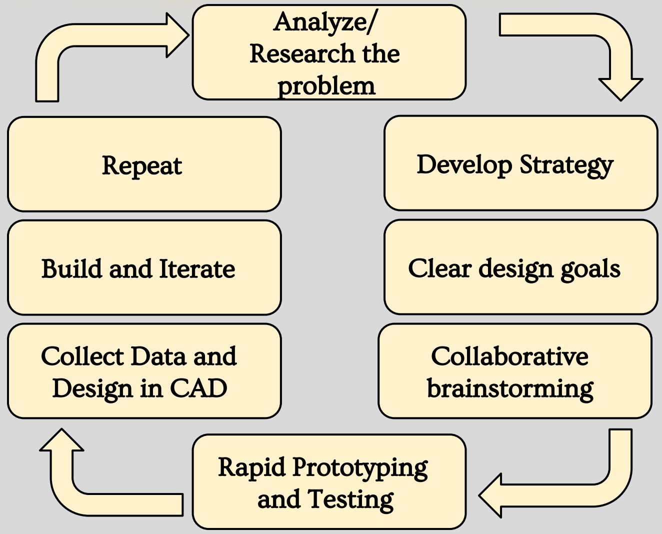


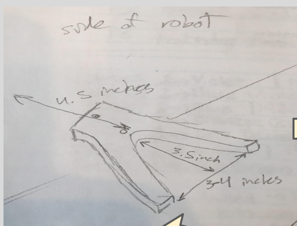
Peace Through Robots

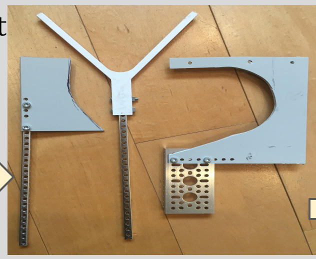
This season we partnered with Dr. Springer at the University of Edinburgh to help her research how inexpensive robotics programs can help develop stability and bright futures for war-torn countries
Our work there turned into additional opportunities to help pilot programs in Columbia and Sri Lanka. We helped the local faculty learn how to educate young students on Arduino technology while inspiring a love of STEM. The pilot programs supports approximately 110 students and are expected to grow.

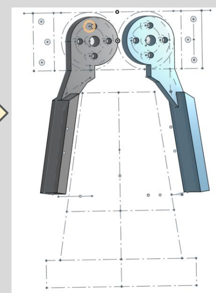
Process and Process Improvement

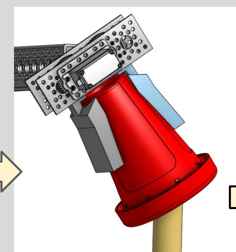
We have been refining our engineering processes for 10 years. While change has been a constant, there are some core aspects of our process that have remained. **We always start by trying to understand the problem we are solving as deeply as we can**, then **brainstorming many different ideas**. **Ideas are often combined** at this stage to produce concepts no one of us would have come up with. **Then we prototype, test, and iterate**. **This collaborative approach, based on rapid iteration, has been our secret sauce** from the start and remains to t

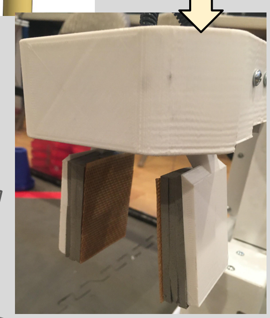












Process Evolution

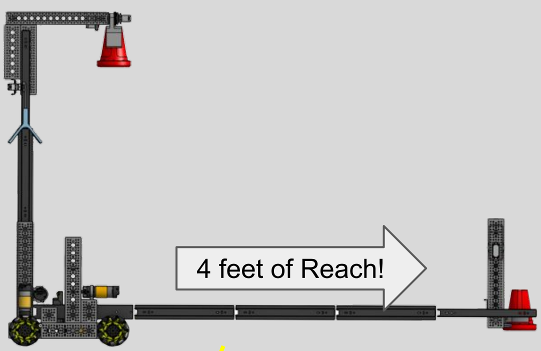
Season	Evolution	Reflection
2015-2016 Trash Trek	Consistency testing	A powerful tool for better robot performance, it became a standard part of our toolkit
2016-2017 Animal Allies	Modular design	In FLL, quick attachment swaps are critical, this was the key that unlocked that.
2017-2018 Hydrodynamics	Refined brainstorming, faster iteration.	Thinking outside the box, and letting the results/data guide us, led us to a World Championship
2018-2019 Rover Ruckus	Trello for tracking GitHub for Source Code	Unleashed the power of software to keep us organized while we iterated quickly
2019-2020 Skystone	SCRUM. Strategy driven design	Having a clear prioritization of tasks and revisiting that frequently in Stand Ups was very powerful for making good use of limited time
2020-2021 Ultimate Goal	Prototype driven CAD (Onshape)	Working prototypes gave us the key design elements and geometry. Those became the basis for our CAD designs, solving integration issues early and resulting in one of our best robots yet
2021-2022 Rover Ruckus	End to end process integration.	From brainstorming to consistency testing, our energy was focused on the critical items and allowed us to change mechanisms where they were not working while preserving what was.
2022-2023 Power Play	Independence & goal/principle driven engineering	Having clear design goals from the start has allowed us to innovate and iterate like never before, while at the same time, creating what we think is our most beautiful robot yet.

Game Strategy and Design Goals

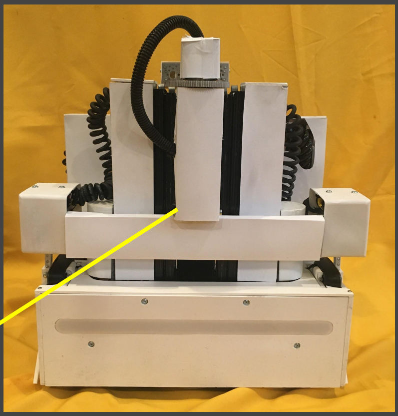
Game Analysis & Strategy

To win PowerPlay, we wanted options in autonomous (cycle, scatter, defend), sub three second cycle times, and the ability to react quickly to a rapidly changing field. Our core strategy is to exit autonomous ahead in both points and junction ownership, then follow the other alliance, dropping cones on theirs, after they place.

22-23 Season Design Goals
Avoid or minimize robot movement (armature is faster and more accurate) But be small and fast to maneuver through the poles quickly when we need to
Be reliable and strong to deal with the high levels of robot to robot contact in this game Place the cones as fast as possible with 100% accuracy (provide ample room for error)
Visually striking and beautiful , blending form and function, closer to EVE than ever before.



These goals led to some key Design Principles that informed our engineering and aesthetic decisions through the season as we iterated .

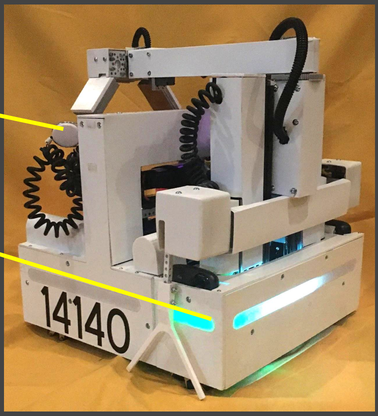


22-23 Season Design Principles

Symmetry : Balance the robot both in mass and appearance, and provide redundancy

Favor Linear Motion : The key to reconcile the somewhat contradictory goals of not moving the robot much, but also keeping it compact to moving very fast when needed

Optimized Paneling : Paneling that fits each need, to perform function and provide form

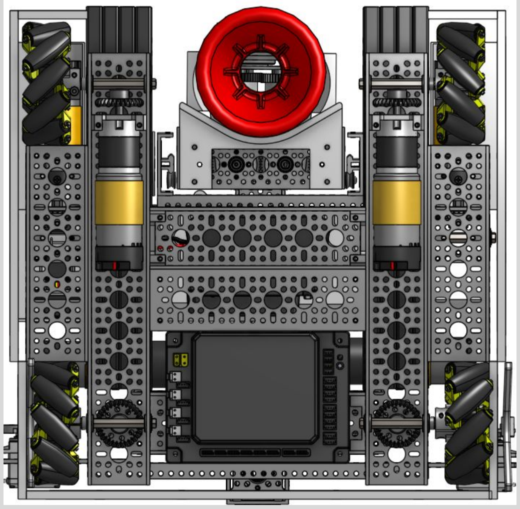


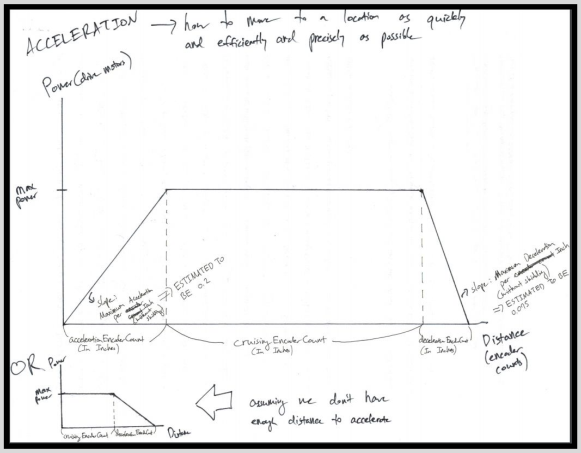
LED Lighting : To give us our signature look and inform the drivers as to robot status

Plenty of Power : To enable both the speed and control we would need for high performance

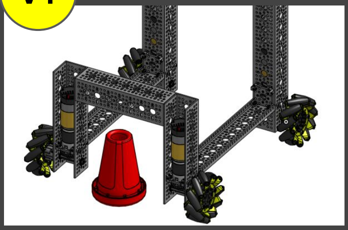
Structure

It was clear that a holonomic drive based on mecanum wheels would be our drive solution for the season. Our software implements a universal drive (based on a trigonometric proof) that allows us to smoothly accelerate, translate, and decelerate our robot in any direction, relative to the field, while holding a heading or rotating to a new heading—*without slipping the mecanum wheels against the mat*. This has given us tremendous control over the robot without using RoadRunner or additional deadwheels. Use of 435 RPM motors at 1:1 gear ratios with the wheels give us both good control and tremendous speed. Testing and calculations indicate a maximum speed of our robot of **~2m/s (2700 max encoder tics/second / 384 tics/revolution * 0.1m wheel diameter * PI)** . However, our smooth acceleration and deceleration curves limit this considerably, while providing excellent control over the robot. This is a good example of our principle of engineering with more power than you might think you need in order to allow for better and smoother control of the robot.



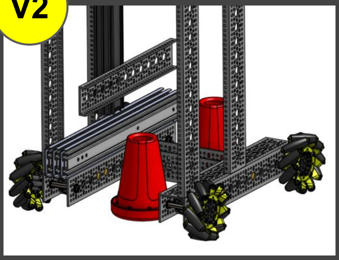


V1



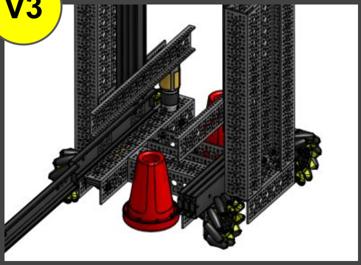
Our **V1** concept involved passing the cone under a cross beam and keeping the rest of the robot middle open. A quick build demonstrated it was not structurally sound

V2



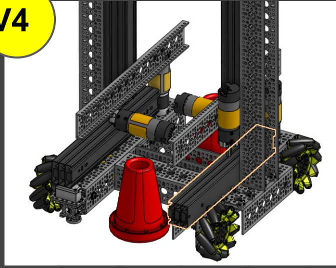
In V2, we moved the cross beams to the middle of the robot to create an H shape to intake on one side and output on the other.

V3



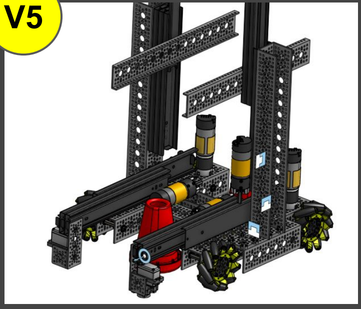
In V3, we modeled side structure and the frame for the gantry that was to carry cones from the front to the back

V4



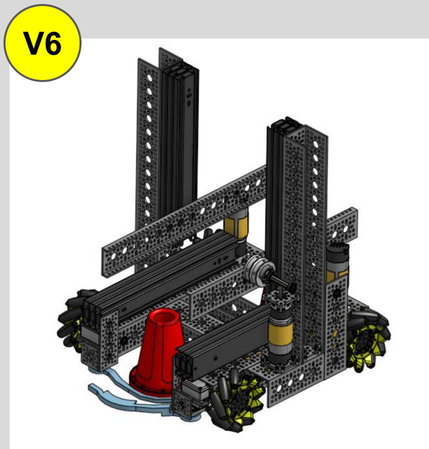
In V5, the motors are now symmetrical and down low, but still not positioned well to accommodate electronics and meet our compact goal

V5



In V6, some out of the box brainstorming has relocated the motors to use some existing dead space. This is the core structure we took to the first meets

Iterating to Sucess



In V6, some out of the box brainstorming has relocated the motors to use some existing dead space. This is the core structure we took to the first meets

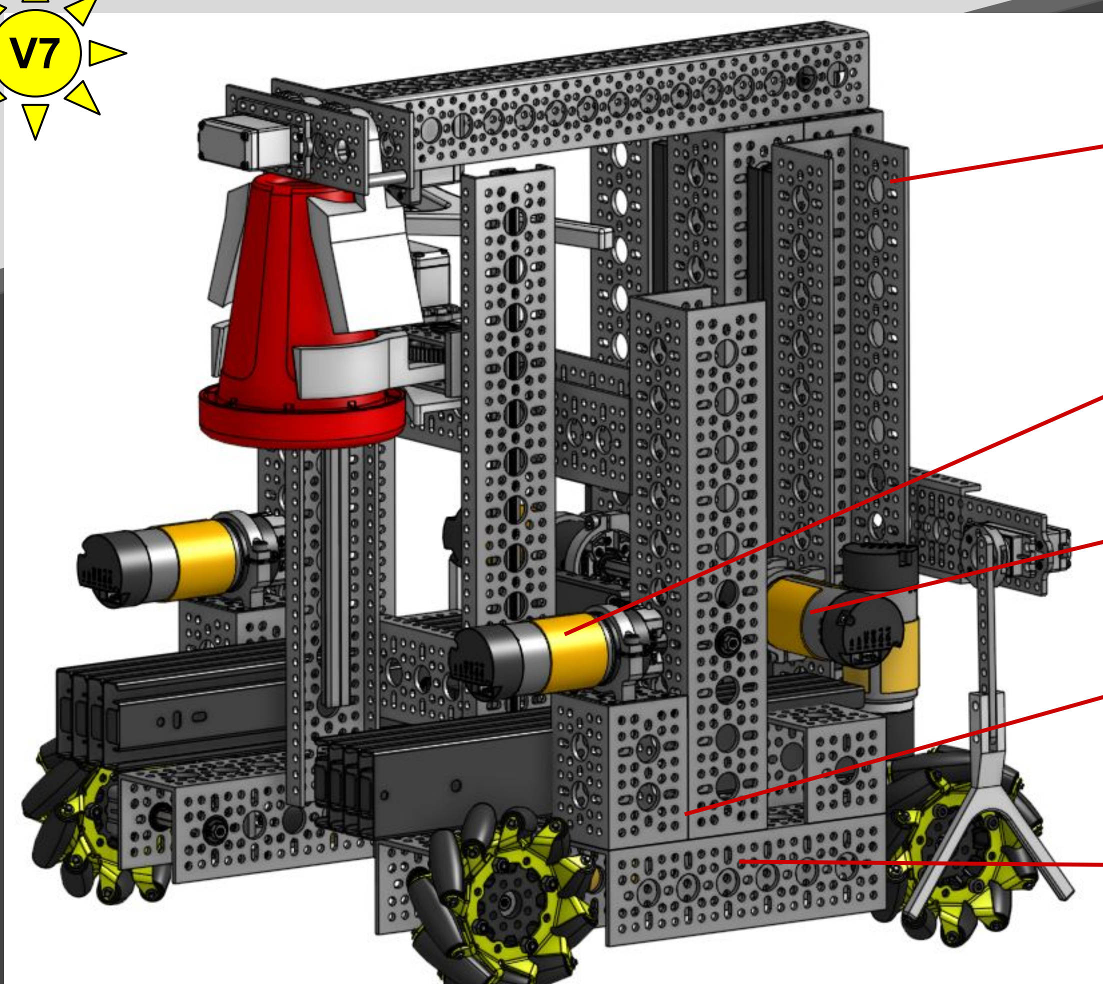
Additional Software Control utilizes our pole detecting computer vision algorithms to localize our robots position during autonomous. In our “scatter” auto, software control extends our extension arms to the wall as the robot approaches it, then monitors encoder positions on the extensions as the robot/wall push the arms back in resulting in a precise location relative to the wall..

V7 is the result of a significant redesign after the gantry delivery mechanism was rejected in favor of our swivel delivery arm.

In this design the spindle motors also find their eventual home resulting in an even more balanced robot.

This is the core structure of the robot as we go to Worlds.

V7



Strong frame to control what little angular momentum swivel arm generates

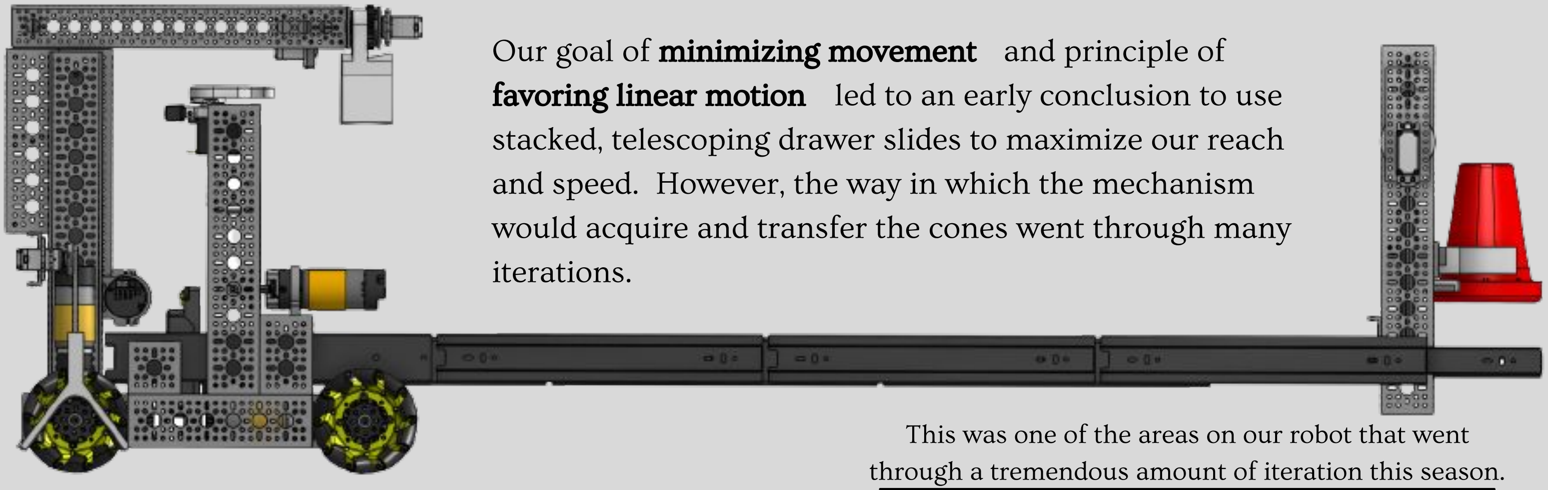
Balanced, redundant 1150 RPM extension motors

Balanced, redundant 435 RPM lift motors

435 RPM Drive Motors located for compact overall size

Majority of mass within a few inches of mat

Cone Acquisition

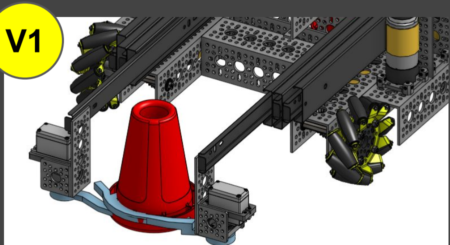
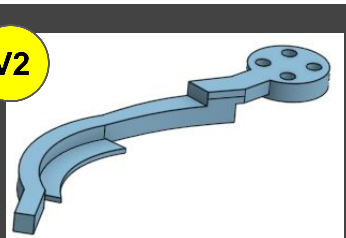
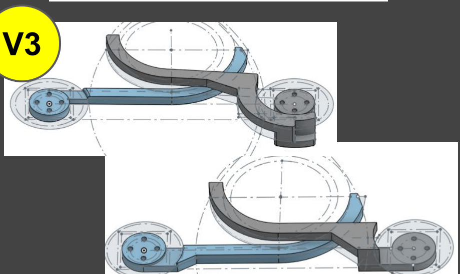


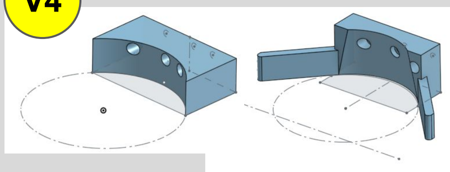
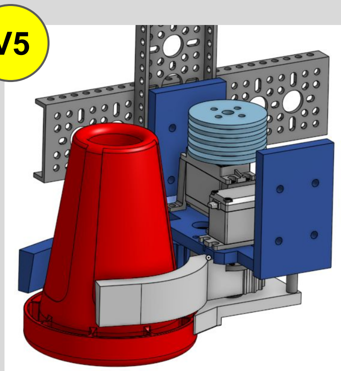
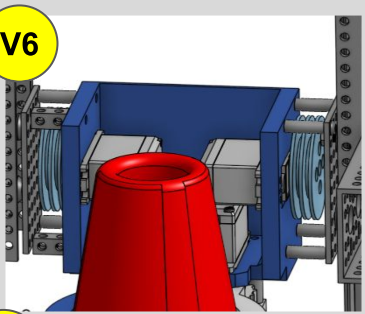
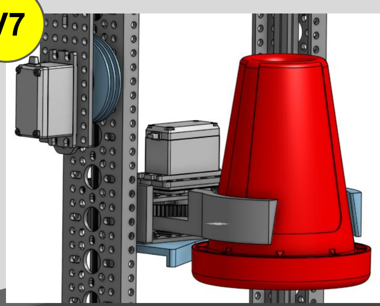
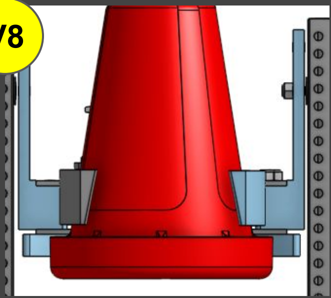
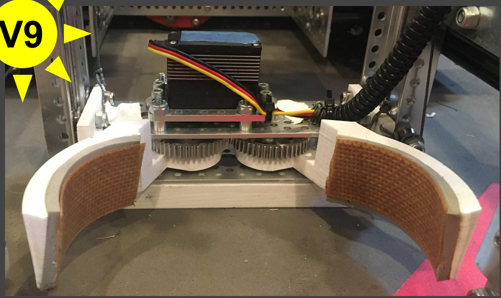
Our goal of **minimizing movement** and principle of **favoring linear motion** led to an early conclusion to use stacked, telescoping drawer slides to maximize our reach and speed. However, the way in which the mechanism would acquire and transfer the cones went through many iterations.

This was one of the areas on our robot that went through a tremendous amount of iteration this season.

Bucket of Previous Parts

Software Control allows us to approach the field perimeter at extreme speed then rapidly decelerate to gently align on the wall, for the perfect cone grab. Encoder feedback allows us to position the robot using the extensions as they touch the wall. Failsafes detect stall conditions and alert our autonomous routines to try something else.

Version	Key Design Elements	Testing and Reflection
V1 	In our initial versions, our cone deployment system could pick up cones from the ground in the front bay of the robot. This meant our cone acquisition mechanism could simply sweep the cones in.	Servos were mounted to allow for horizontal rotation of sweepers. Initial tests would tip over the cones as the sweeper arms would contact the cone below its center of gravity with enough force to rotate it (and tip it over).
V2 	We altered the design of the sweeper arms to try and utilize the lip of the cone to stabilize the sweep and reduced servo speed	While this helped, there was still too much kinetic energy contacting the cone too far below its center of gravity.
V3 	Further revisions of the arms tried to “grab” the cone by gripping it on both sides as the arms closed.	This led to some convoluted designs to allow for maximum room for error while still allowing the arms to fold away.

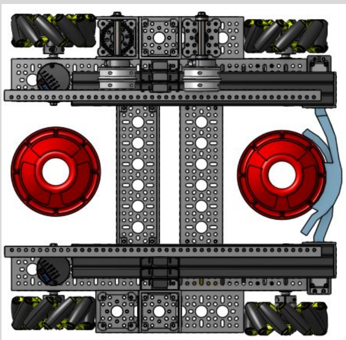
Version	Key Design Elements	Testing and Reflection
V4 	Additional parts were added to "catch" the cone from behind so that the sweeper arms might pull it in and pin it to these parts for the journey back to the robot	While this helped further, we were still hovering around 80% consistency and realized we needed a significant change in direction.
V5 	At this point, we moved to a very different design which involved a "mini lift" at the end of the horizontal slides. This lift would need to grab the cone firmly from the sides so it could lift it up and bring it back in the air. Initially we used one servo to power 3d printed arms and 1 servo with a double spindle to drive the lift	While this design worked well, the lift was far too slow, requiring over 2500 ms to travel from the bottom to the top where the cone could be transferred to our deployment gantry. Since the horizontal extensions could retract in <600ms, this was not fast enough. Our calculations showed that a faster servo would not have the needed torque
V6 	We added a 3rd servo so that we could double the lifting power and eliminate the friction from the 90 degree bend in the lift cable	While this helped further, we were still hovering around 80% consistency and realized we needed a significant change in direction.
V7 	In this version, we moved the duel lift servos to the lift towers themselves to reduce weight substantially. We also moved to light-weight aluminum gears and top and bottom plates to make the mechanism more compact.	This was a major breakthrough that was now giving us sub-second travel times from the top to the bottom. Remaining problems concerned the vertical reach of the lift and room for error on the grab.
V8 	We extended the 3d printed side parts to allow for more reach downwards and modified the "pusher" plate on the bottom to guide the cone better	This revision added weight (and slowed us down) and further testing revealed the "pusher plate" was causing issues without adding value. (The grabber arms were already providing the needed room for error.
V9 	In our current design, the mechanism is extremely lite and compact, allowing for a reliable transfer. The pusher plate is intended only to help near the top of the cone stack. This has allowed us to achieve all of the related design goals of speed, reach, accuracy, and consistency.	

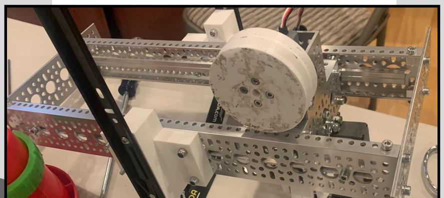
Cone Deployment

"It's all in the wrist"

This aspect of our robot has been through the biggest and most innovative changes this season. A complete rethink of design after our League Meet #2 unleashed a great deal of new capability leading to our standard, scatter, and defensive autonomous routines as well as the ability to rapidly shift the deployment target from junction to junction as the game is played.

Version



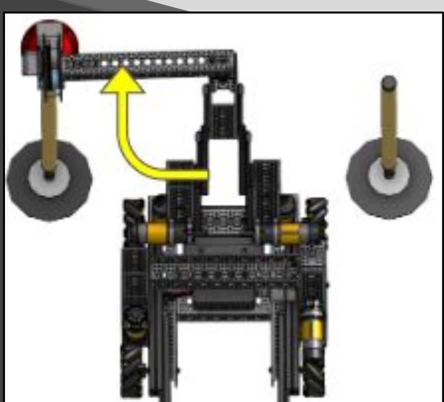


Key Design Elements

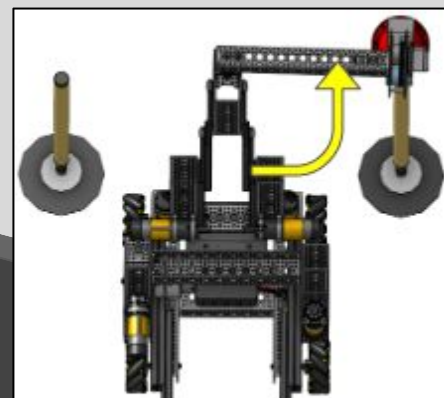
In our V1 concept, we developed a gantry that could shuttle cones from the input bay on our robot to the output bay. This was intended to work in concert with the cone sweeper (to pull cones in) and our break-beam pole detection strategy for aligning on poles quickly for the drop.

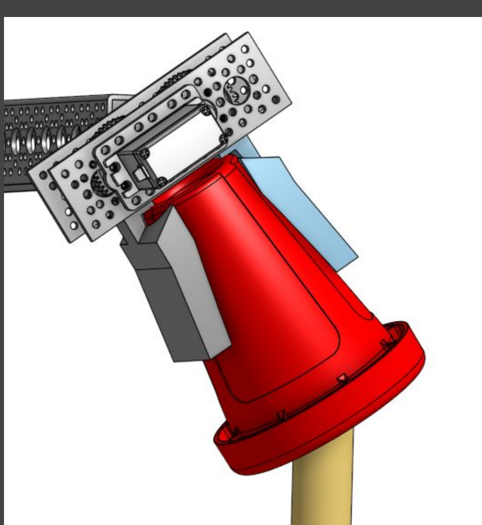
Testing and Reflection

This mechanism worked well and allowed us to place all 6 cones on the nearby "low" pole during autonomous at a 75% success rate during Meet #2. However, it still required a substantial amount of robot movement and thus did not truly meet our design goals.



After Meet #2, we did a complete redesign of this element of our robot. With the mini-lift now in place in our Cone Acquisition mechanism, we no longer needed to reach the ground during transfer, allowing for the breakthrough innovation of our swivel arm which could place cones in a 360 degree circle around the robot without moving the robot base

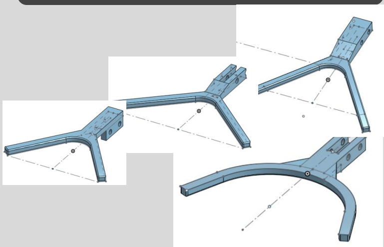


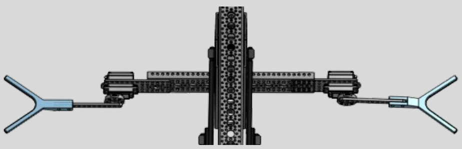


We also added a "wrist" to our swivel arm to allow us to use the cone (at an angle) to essentially brace the pole and even push it into a better position for the drop. Subsequent software control allowed us to automatically rotate the cone on to the pole for the drop and then rotate the grabber back off of the pole to avoid interference.

In Meet #3, these innovations paid off, leaving us in the #1 ranking position going into the League Championship. However, while we had successfully achieved our goal of minimizing movement, our accuracy rate in both autonomous and telop for drops was still not where we wanted it to be.

Version





Key Design Elements

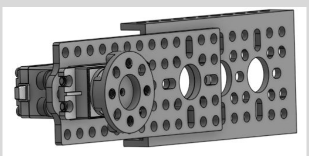
Further application of our brainstorming and prototyping process led to our "Just In Time" pole bracers. Initially we tried a number of designs and angles, 3D printed in PETG

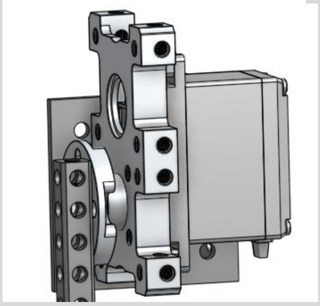
A strategy was developed to mount the bracers on servos, on either side of the lift, to allow for "Just In Time" deployment of the bracers

Testing and Reflection

Testing showed that an optimum angle for pushing the pole sideways while still letting it settle into the V shaped notch was around 36 degrees. A late breaking game ruling caused us to iterate further.

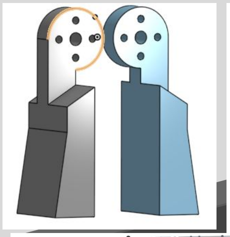
This strategy added the missing room for error and along with some fine tuning of our software, is now part of our 98.7% accurate autonomous and rapid teleop deployment

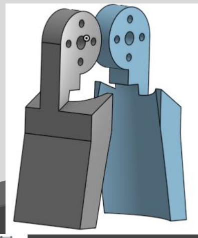




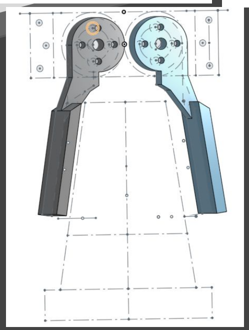
We also iterated on the way in which the bracer servos were mounted. The original design was strong enough but did not protect the servo internals well and resulted in a broken servo shaft at the League Championship. The latest revision uses GoBilda's new compact servo blocks

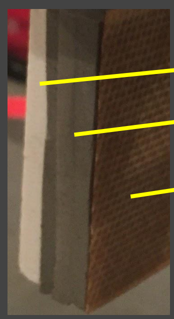
Software Control allows us our lift to travel up and down extremely fast, braking just in time before it hits the bottom. Finely tuned timing loops rotate the wrist and swivel arm in conjunction with encoder readings from the lift motors to ensure cones are placed as fast as possible. Failsafes protect the system in case of unexpected interactions with other robots.





We also iterated on the shape and size of our deployment grabbers, trying flat, oversize, and cone fitting shapes. In the end, the winning design was a very thin, but strong PETG printed backing, with several layers of foam rubber on it (for compressibility) topped by a thin silicon mat (for grip). We have had 100% success with cone grips with this design.





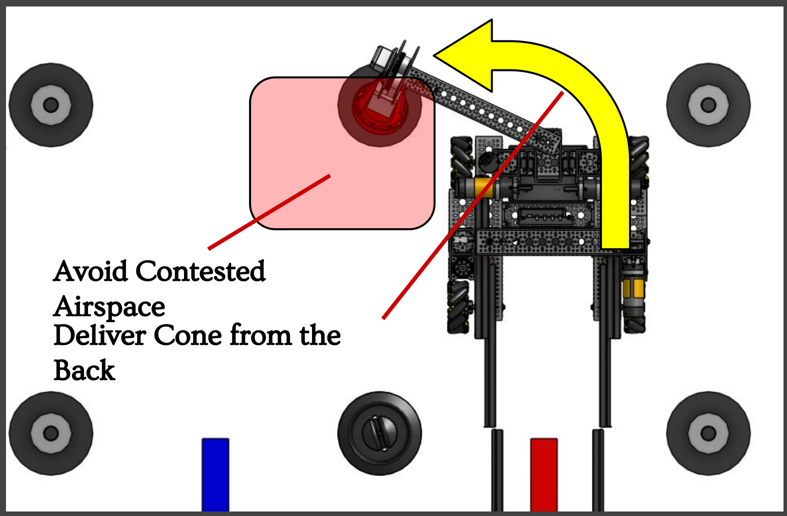
PETG structure for strength

Compressible foam rubber to conform to cone

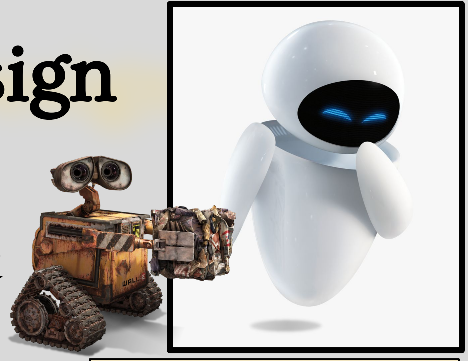
Thin silicone mat for grip

The Secret Weapon

This deployment system has also enabled an approach to autonomous that allows us to avoid contact with another robot going for the tall center pole. By swinging our deployment arm around the back of our robot, we can avoid the airspace the other robot is operating within.



Paneling and Industrial Design



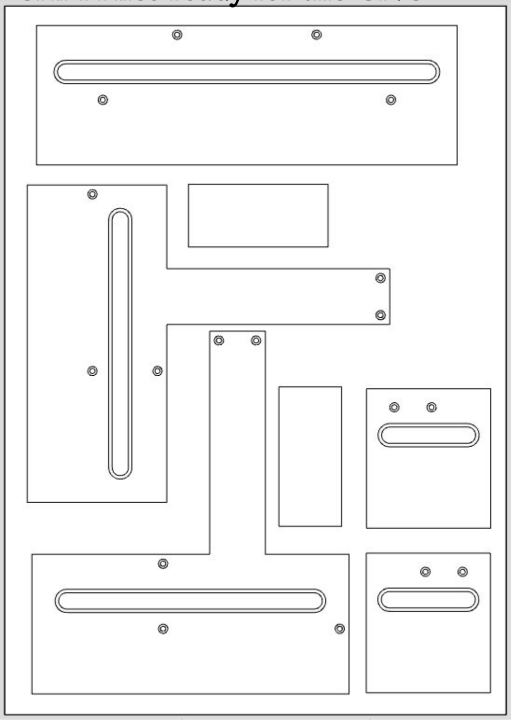
EVE, the love of Wall-E's life, and our Design Inspiration

Let's face it, FTC Robots are not often beautiful. A typical hair dryer has better industrial design. Our goal from the start of FTC was to change this. We took EVE, the love of Wall-E's life as our design inspiration and have been getting closer ever since.

Excellent paneling was central to several of our Key Design Principles and, while we had solid experience from previous seasons, we knew we would need to iterate here as well. Over the season we tried some new techniques and materials including using a CNC to cut out our main panels from expanded PVC foam, using a laser printer to cut out our translucent polycarbonate insets, and using a resin based SLA 3D printer to get extremely lightweight/thin but tough panels for some key parts.

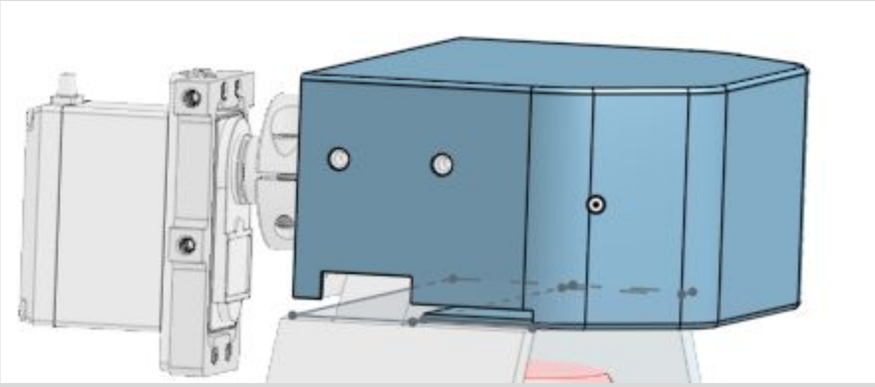
Material	Manufacturing	Use
PVC Foam	CAD and CNC	Flat panels, lightweight and tough.
PETG	CAD and 3D printing (extrusion)	Very thin panels that can take a beating, complex shapes
Polycarbonate	CAD and Laser Cutter	Translucent panels for LEDs
Resin (various)	CAD and SLA printer	Very thin and complex parts (motor covers)
Thin Sheet Vinyl	Scissors!	Lightest weight, no contact

CAM Files ready for the CNC



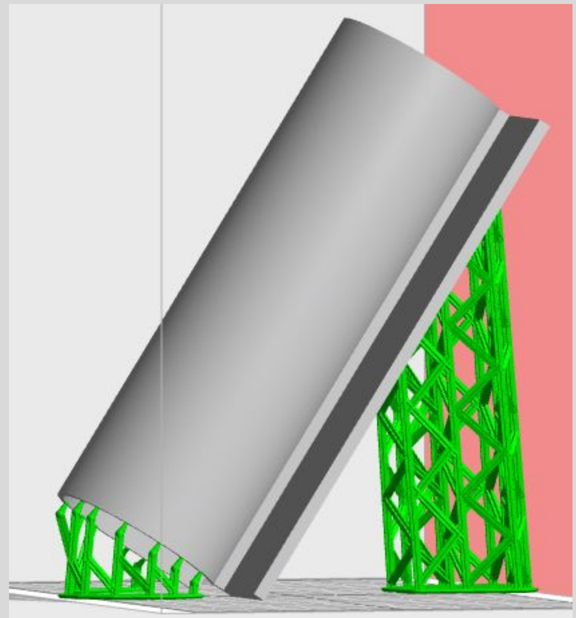
In Context Part Design in OnShape

Very helpful for complex panels that must fit precisely

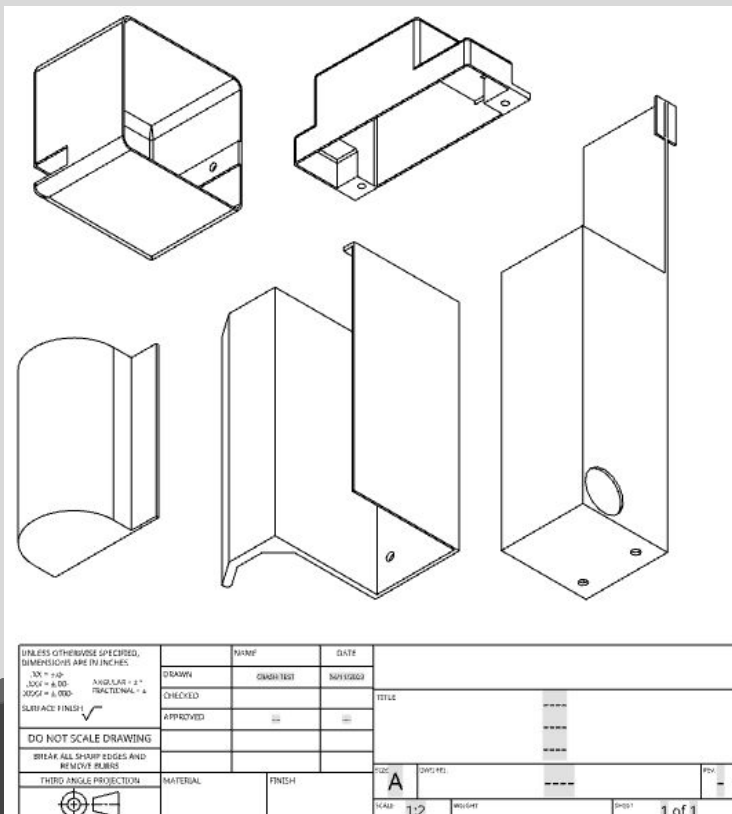


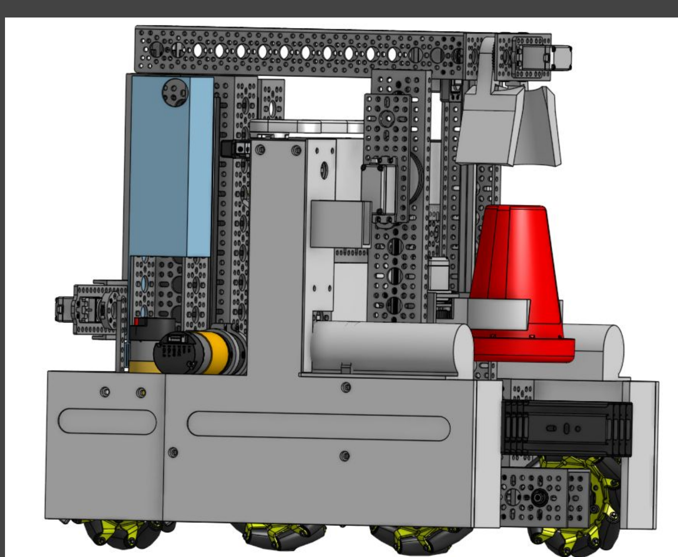
SLA Printing

Front Motor cover ready for printing



CAD Drawings of Various Panels

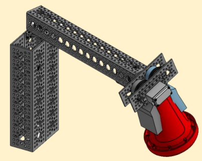
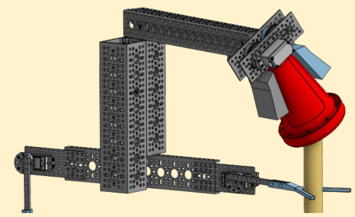




Work in progress on panelling in OnShape CAD software

Innovation

Our bot has what we believe is a globally unique combination of 3 main innovations. These innovations work together to enable multiple, diverse autonomous modes, rapid, on-the-fly junction targeting changes, and world-class speed.

Innovation	**<u>Extending Cone Grabber</u>** 	**<u>Swivel Arm and Wrist "It's all in the wrist"</u>** 	**<u>"Just In Time" Pole Braces</u>** 
How it Works	• From 4' away, our bot can reach into the substation, grab a cone, and withdraw in 500ms • During Autonomous, we can cycle all 6 cones onto a high pole without moving the robot • Effectively disappears into the robot when not in use allowing for fast and accurate robot movement.	• 360 degree reach with a swivel wrist allows us to rotate cones down onto the top of poles at various angles. • Minimizes mass subject to rotational momentum, allowing for VERY fast speeds. • Scores on both sides of robot without movement.	• Dual pole braces on each side of the cone delivery lift • High torque servos to extend brace and push pole into position "Just In Time" for the drop, quickly returning to stowed position • Only extended for a few milliseconds during the cone drop, allowing for easy/fast driving to the pole • Significantly improves autonomous success

<u>The Unique Combination of these Innovations Enables:</u>

- Sub 3 second cycle times on any junction on the field
- Sub 2 second cycle times on nearby junctions
- Standard 5+1 as well as 5 junction scatter autonomous modes with high consistency
- Rapid, on the fly, target junction switches as robots jockey for position
- Better compatibility with a wide range of alliance partners
- The Secret Weapon
  This deployment system has also enabled an approach to autonomous that allows us to avoid contact with another robot going for the tall center pole. By swinging our deployment arm around the back of our robot, we can avoid the airspace the other robot is operating within