Season Summary

516 Gears of Fire

Introduction

Maintaining a successful robotics program is not as easy it may seem. With myriad hours of hard work, our robotics program has flourished far beyond what we had expected. Our robotics program at Palm Harbor University High School, our school, participates in the FIRST Tech Challenge. Designed to challenge students of all ages, FIRST Robotics, www.firstinspires.org, organizes various challenges for different age groups. The FIRST Tech Challenge inspires high schoolers to improve their **building** and **programming** skills through Java on an Android platform. **CAD** is used to help design our robots and various systems and subsystems. The FIRST Tech Challenge also instills important life skills in students as students are judged on their ability to outreach and set up community events, their creativity, their public speaking skills, and their documentation ability.

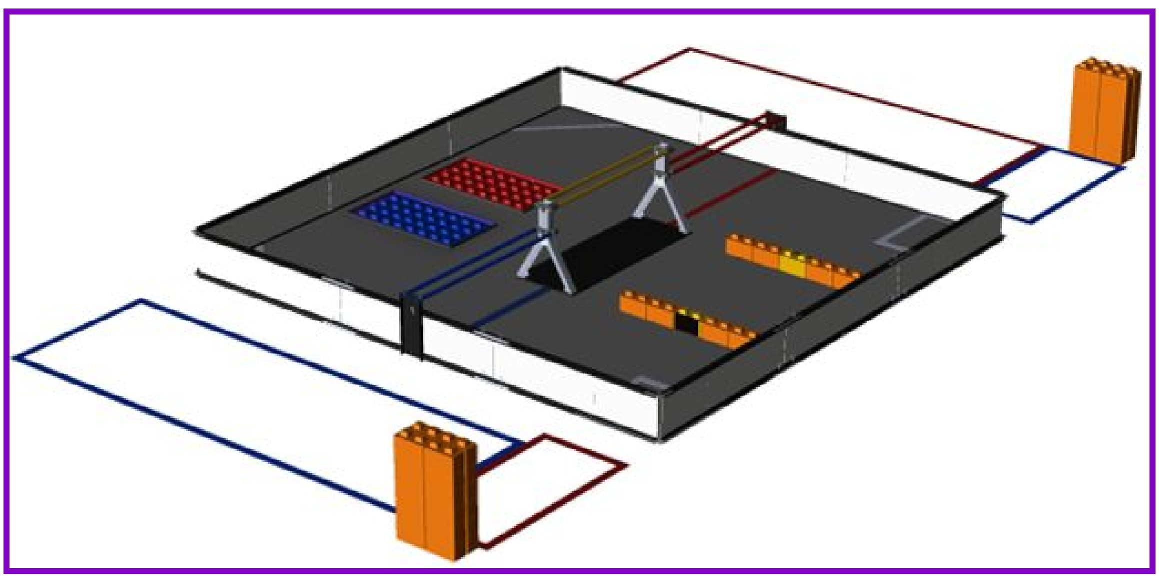
In addition to building award-winning competitive robots, our teams focused heavily on important **business and sustainability principles**. For example, our team has been in contact with teams across the United States and Brazil. These teams have requested our help on a variety of subjects from building to programming. Also, we participated in a demonstration at the Glacier Children's Museum, mentored several local middle school Robofest robotics teams, and assisted any teams that required assistance at competitions. We recently held a demonstration at our local Raytheon firm. Due to the great expenses of maintaining a successful robotics program, we focus greatly on developing positive relationships with local businesses. Our team has raised almost $1000 in funds.

At the Florida State Championship in Jacksonville, our team won third place for the Control Award. At the League Championship, our team won the Connect Award, the Compass Award, second place Inspire, second place Innovate, and second place Design. Overall, we are extremely proud of the accomplishments of our team and the club as a whole!

The Game

Every year, FIRST designs a new game for the FIRST Tech Challenge, with this year's game having a construction-based theme of building skyscrapers, named **Skystone**. The game is divided into two distinct periods, a **30-second autonomous period** and a **2-minute TeleOp driver-controlled period**. Teams play on two-team alliances: Red Alliance and Blue Alliance.

The autonomous period objectives include transporting Stones under the alliance bridge, moving the foundation into the building site, and parking under the alliance bridge. In the TeleOp period, teams move the yellow Stones from their starting position in the Loading Zone to the foundation in the Building zone, stacking the Stones on top of each other to create Skyscrapers. The last 30 seconds of the TeleOp period are considered the **"Endgame" period**, in which teams can complete special objectives to earn additional points. These objectives include placing a capstone on the foundation or on top of a Skyscraper, moving the foundation out of the building site, and parking in the building site.



SKYSTONE

PRESENTED BY Qualcomm

Design

While designing and building the robot, we tried to follow a general process of **prototyping, testing to find weaknesses and inefficiencies, constructing a new prototype, and creating a finalized design**. However, after our competitions, we usually have to make improvements to our designs as flaws are discovered throughout competitions. Throughout our design process, our robot underwent drastic changes this year. We made major changes in almost every aspect of our robot since the start of the season. Our final robot was based on the fundamental design of **a two stage transfer method** in which we **intake stones, move them to the middle of the robot, and stack them on the foundation**. Our robot consisted of eight main subsystems which will be discussed in this section:

- Drivetrain
- Intake
- Extension
- Transfer
- Lift
- Capstone Placer
- Autonomous Stone Grabber
- Platform Mover

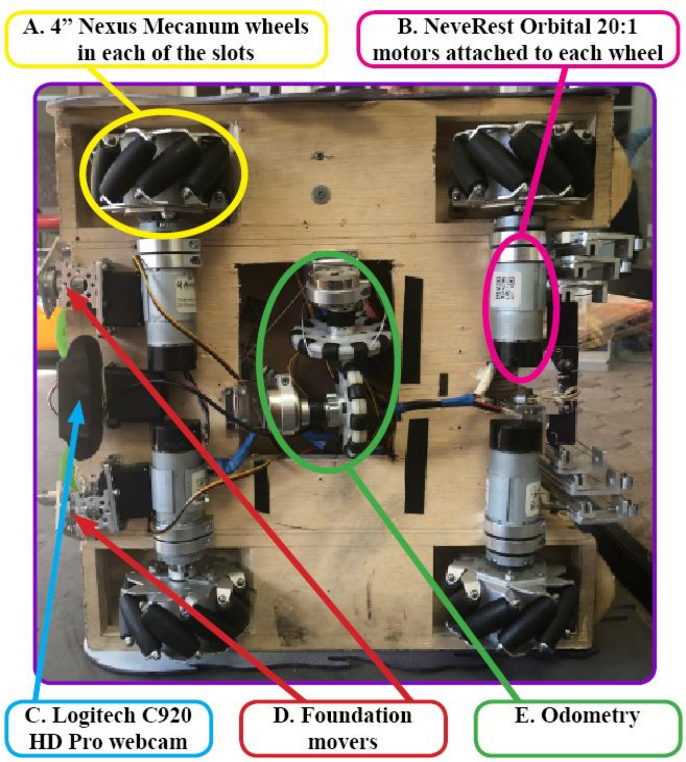
Our robot, Woodie!

Drivetrain

Our drive train was made of **custom-cut-plywood**. We believe it was one of the most unique parts of our robot. It allowed us more room for customization such as mounting electronics and all of the systems needed to complete the tasks in this year's game. While our robot weighed about 32.6 lbs, it was still **incredibly fast and efficient** for navigating the field. We are proud of our custom plywood drivetrain as we believe that it is much more creative and unique than using other materials such as Actobotics or Tetrix. Our drivetrain consisted of parts necessary for objectives in both autonomous and TeleOp such as a fast and efficient drive system, odometry, foundation movers, and a web-cam. Compared to the rest of our robot, our drive system underwent the most drastic changes. While we initially used an Actobotics drivetrain from last year's season, we found that was **unfamiliar to our build team this year**. Therefore, we switched to a plywood drivetrain. In addition to the reasons listed previously, our build team worked more proficiently with wood than Actobotics. The plywood drivetrain proved to be sturdy and effective while not hindering our movement on the field.

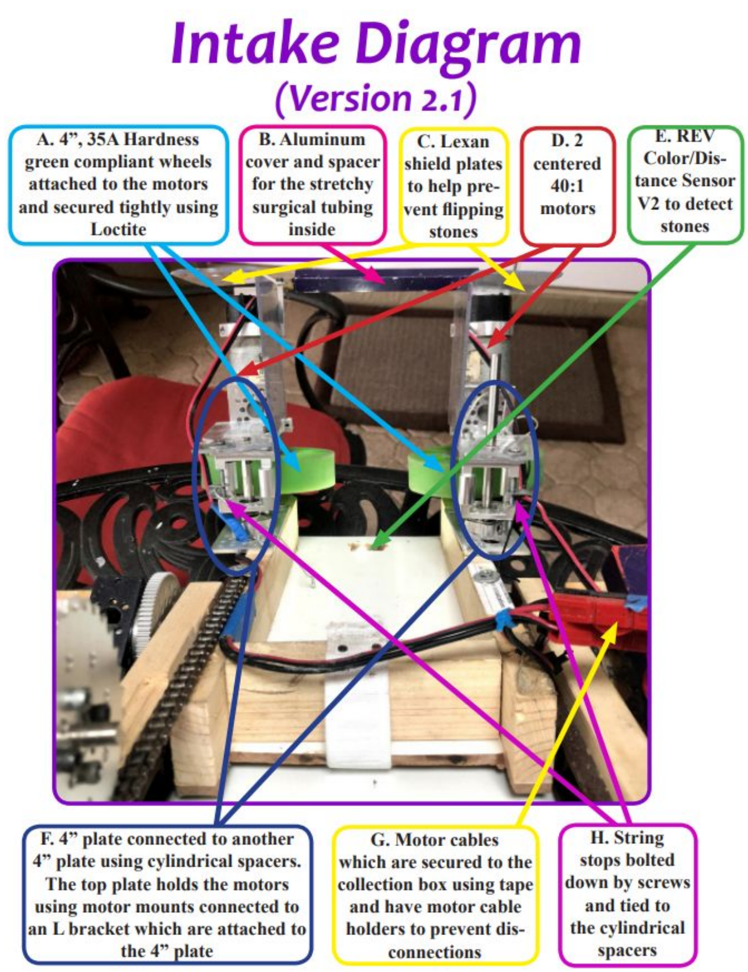
Completed first iteration of the drive train

Drive train after switching



Intake System

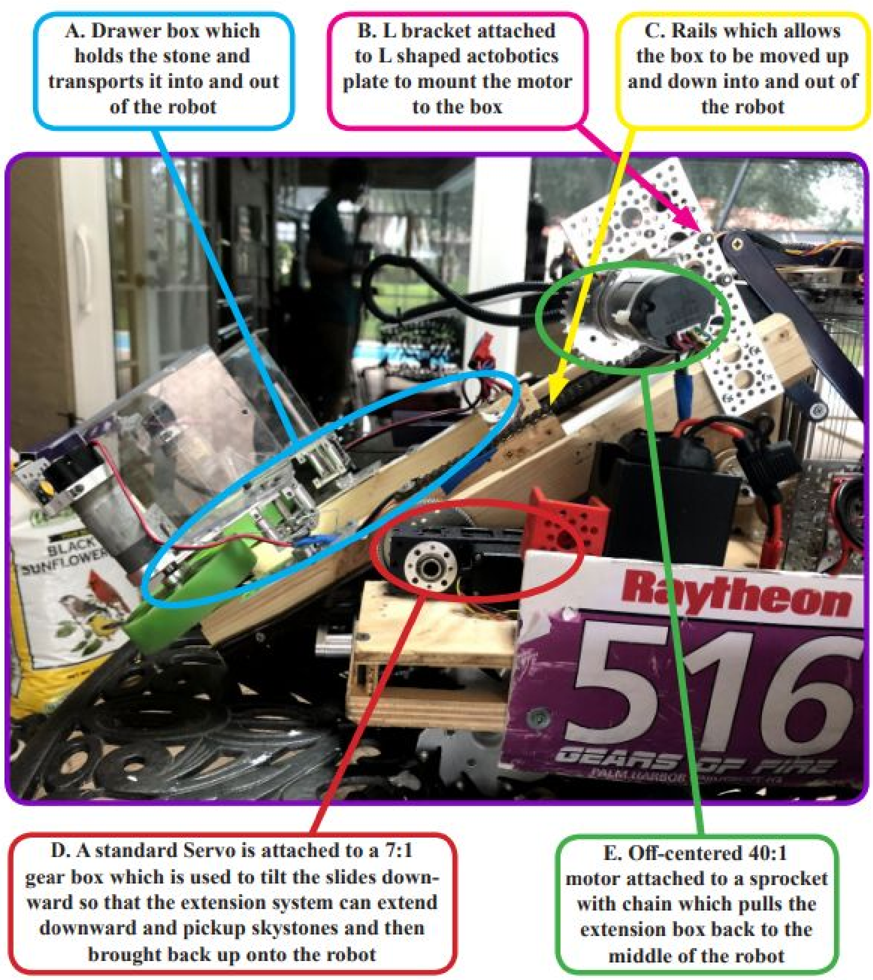
In order to collect stones, we made an **intake system** using **green compliant wheels** that had a good grip and easily closed around a Skystone and intake them into the extension system box. Our intake system was highly effective, taking **only a few seconds to intake stones**. Furthermore, we believe that the many iterations and changes we have made to the intake system has made it incredibly reliable. While we did have issues with the reliability of the intake, the intake system was one of the most crucial and efficient systems of our robot. Our final intake used green compliant wheels attached to motors which spin the wheels and intake blocks once we drive up to them. The intake system underwent several iterations, including an original suction idea, a claw design, and our final green compliant wheel design. We chose our setup as it is simple, yet effective. The intake system was extremely reliable. After the many iterations, we finally fixed the majority of issues with it. We had **many issues with the intake originally**, because our original claw design was not accurate at all. The first version of our second design broke during competition. Nevertheless, **our intake has become one of the systems we are most proud of**.



Extension System

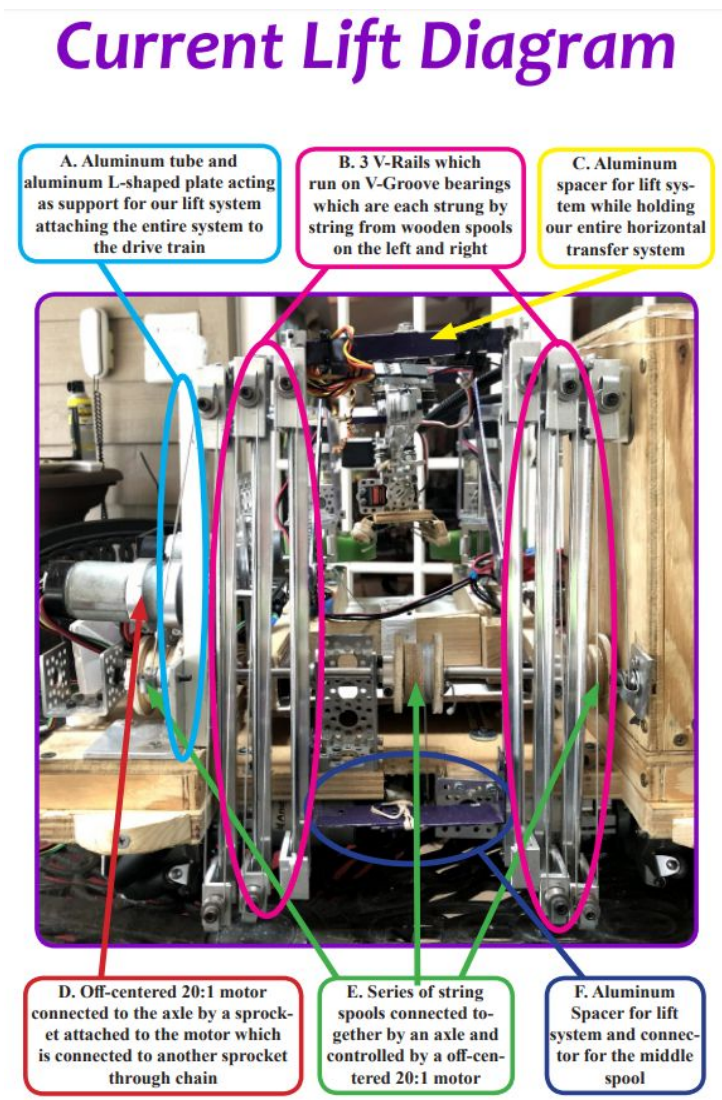
Our extension system was a key subsystem of our robot as it allowed us **to transfer stones from the field using our intake system to our placing system**. It was one of the most unique parts of our robot as our system of having the intake attached to an extending and retracting box is different from most teams in our league. Although we did not originally plan to create a complex extension system that would add extra steps to our scoring process, switching the drivetrain from the old actobotics iteration to our custom plywood design necessitated a mechanism by which to raise stones into our robot. As the drivetrain mainly consisted of a raised, flat piece of wood, **the intake would be too high to reach blocks on the ground**. We therefore decided to attach the intake to a horizontal, drawer slide-based extension system connected to a servo which could angle it to the ground, and bring stones from the field into our box. We are particularly proud of this extension system, as it is very fast and efficient, light weight, and unique; **we were one of the only teams who moves the entire intake system for stone collection**.

(Version 2.1)



Lift System

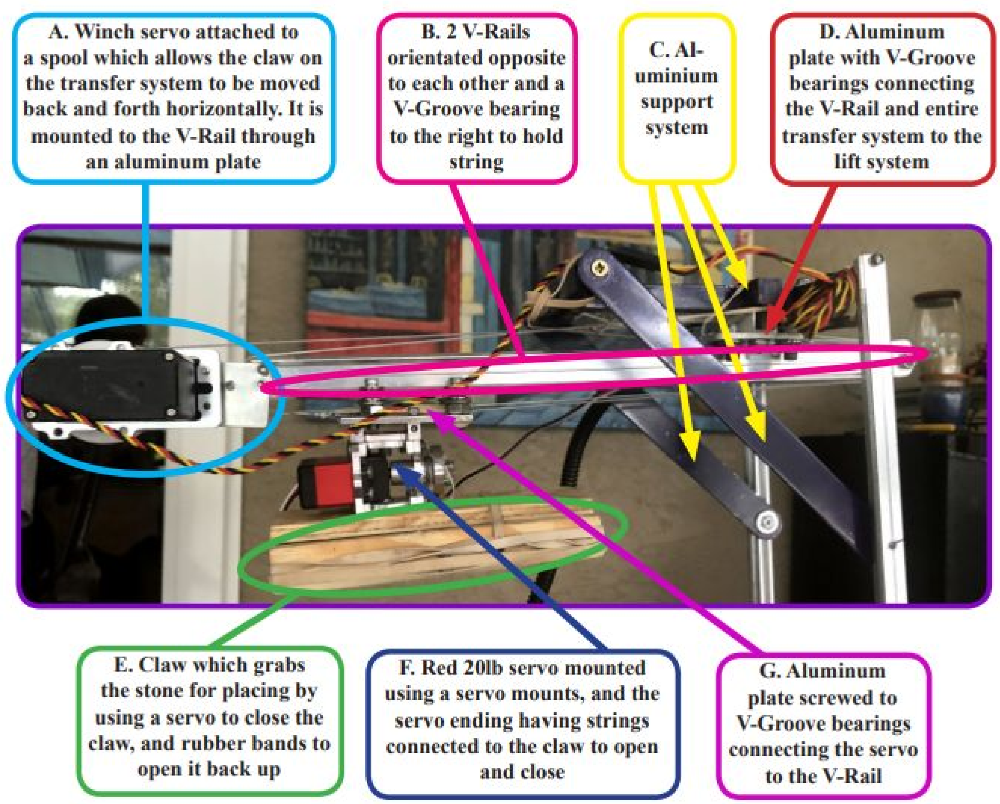
Our placing system had two main parts, which we have called the lift system and the transfer system which work in unison to place stones. The lift system **allowed us to move stones vertically**. It was fast, and tall enough to allow us to stack up to 8 stones high. Although the amount of stones we could stack was limited by time in matches, our lift system was **incredibly fast, efficient, and reliable**. While we originally planned on stacking using an extend-able claw, our switch to a dedicated intake system required a dedicated placing system in order to stack stones. Because of this, we decided to use an **highly custom** lift system consisting of **V-Rails that are moved using three spools on an axle connected to a motor to move it**. The lift system was one of the most unique systems on our robot as it uses three custom made spools which were made to the exact size required as well as using many custom made aluminum pieces to support it all. The intaken block would be grabbed by our claw which is then raised up to the level needed and placed on the foundation. The system was overall very efficient and reliable while being incredibly unique to us which we are proud of.



Transfer System

Our transfer system was crucial to our robot as it **allowed us to move stones from the middle of the robot to the foundation for placing**. The system was also reliable as it almost never fails and will always pick up and place the stone consistently. We based the grabbing design off a similar clamp-like mechanism that grabs the knobs of the stones. With the creation of a new placing system, we needed a way to get the stone from the extension box in the middle of our robot to the back of our robot. The placing system is another highly customized system which we are proud of. The transfer system consisted of a **servo attached to a spool to move a highly customized wooden claw** which grabs onto the stone to the back of the robot. Originally, the transfer system was only held in place using a custom aluminum tube in between our lift slides and would bend easily. We fixed this though by adding extra custom-made aluminum supports attaching the horizontal transfer V-Rails to the vertical left and right vertical lift system rails.

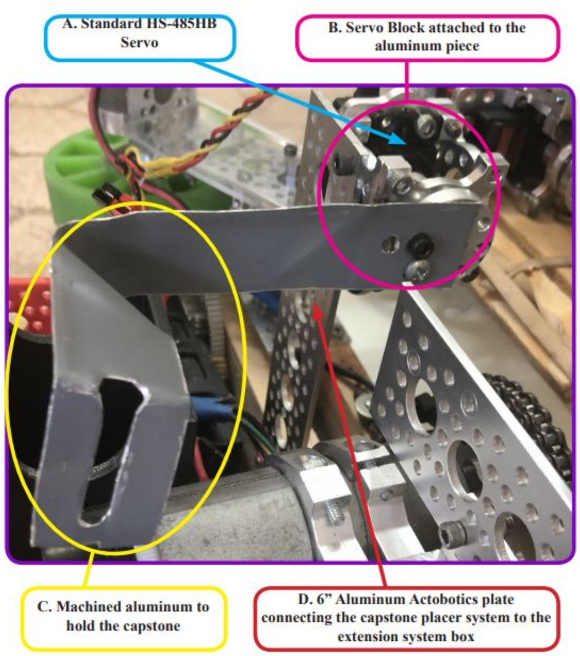
Current Transfer Diagram



Capstone Placer

Our capstone placer was a crucial system to our robot as it is very efficient, simply **dropping our capstone on the last block we place**. Although we have used capstones in the past, we never effectively used a capstone during competitions or implemented a capstone placer mechanism onto our robot until a few weeks before meet 3. The capstone placer is crucial, as it scores us five extra points for being placed onto the foundation, and an extra point for each level of the skyscraper. Originally, using TinkerCad, we made a 76.2 cm x 76.2 cm x 101.6 cm block-like capstone for the scrimmage. However, once we 3D printed it, the capstone did not print correctly and we reprinted it. Ultimately, the capstone proved to be ineffective with our already inefficient claw intaking and placing system.

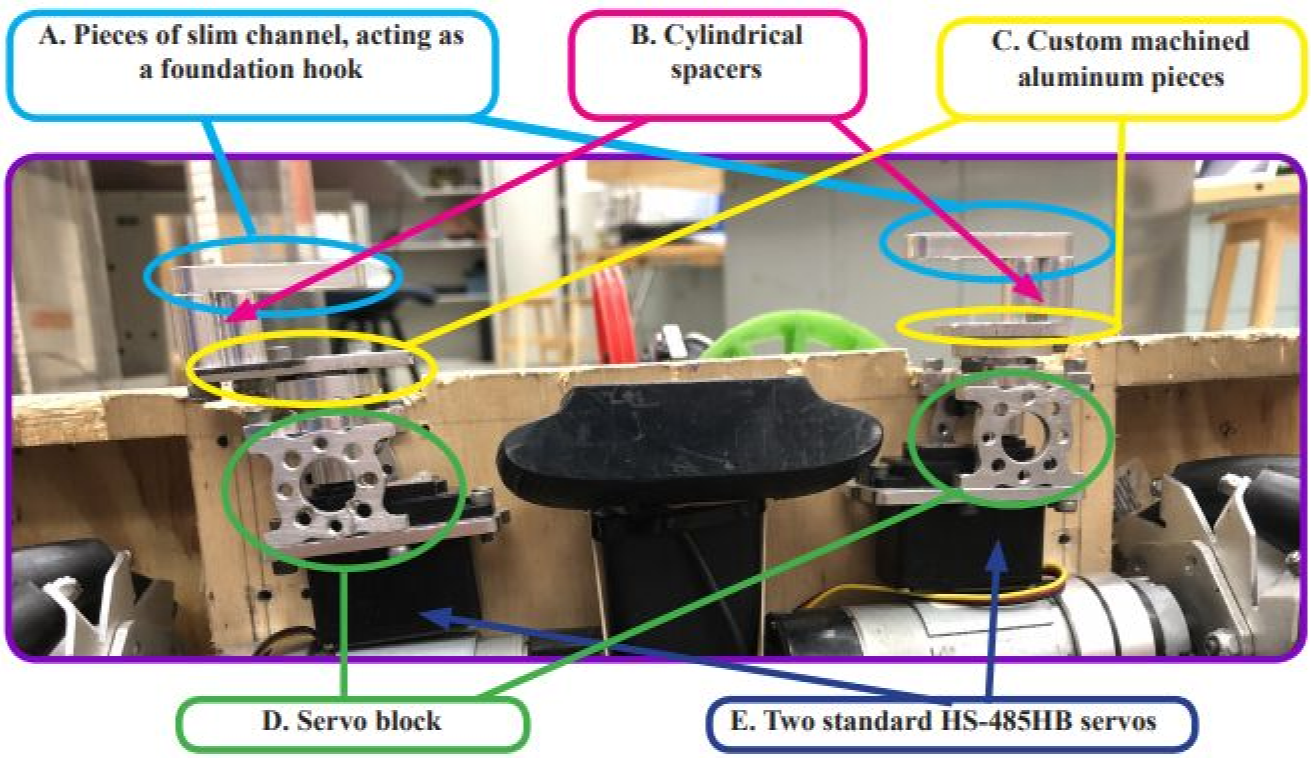
In the second design of our robot, we reprinted the Capstone in order to make it bigger and sturdier, with more supports and denser printing. However, **the capstone no longer worked with our new intake system and could not be used at all**. Because of this, we made **a new cardboard capstone** with a completely hollow underside and wooden knobs for the first meet. The capstone was shaped similarly to a stone, allowing us to intake and place it efficiently. Despite this, we found it to be inefficient as it took up to 15 seconds to place the capstone, and often was worth less points compared to other objectives in the game, especially since we were only stacking 2-3 stones per match.



Foundation Movers

Our foundation movers were a simple yet crucial system to score more points. For the game, repositioning the foundation is crucial, as it gave us 10 points during Autonomous and 15 points during TeleOp. Our foundation movers were highly effective, as they could **reliably and efficiently reposition the foundation**.

Our final foundation movers were much more effective than our older ones. The platform movers were on the sides with the webcam in the middle. Our platform mover used two standard HS-485HB servos with each servo attached to an actobotics plate through an adapter. The plates had a thin metal rod attached by cylindrical spacers. Normally, the mechanism is horizontal.



Autonomous Stone Claw Mover

We created a **prototype Stone Mover** in order to **grab and place stones quicker than our intake system during Autonomous**. Comparatively, our stone mover is faster as it simply has to grab the stones and then place it on the foundation. The Stone Mover doesn't have to turn or wait as long to intake and place stones. With our new stone mover, we are able to quickly drive up to the stones, and pick up the Skystones. We are then able to quickly move to the foundation and place the stones, as since the claw is on the side of our robot, our robot only has to make forward and backward motions. As a result, it allowed us to be **more precise and accurate during Autonomous compared to using our intake to score the stones**. In testing, we also added foam to the sides of the stone move in order to be more accurate in grabbing stones.

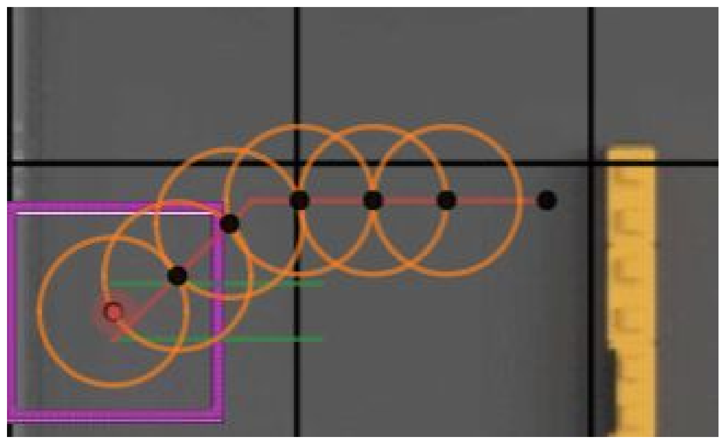
Stone mover opened during auton-omous before grabbing

Stone mover clamped around the stone

Programming

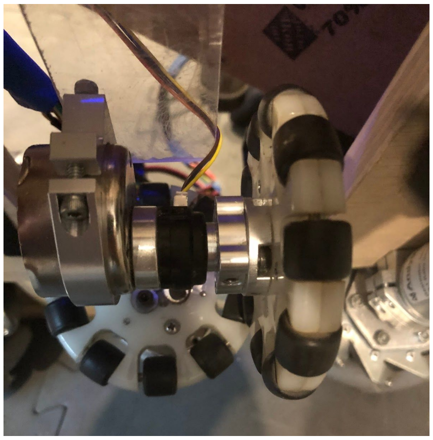
Programming this year was particularly challenging yet rewarding for our team, as we committed ourselves to a **mathematical theory-based approach** heavily reliant on **incorporating real-world engineering algorithms** into our programming designs and finding ways to apply mathematics to **maximize efficiency and enable our robot to correct inaccuracies in movements**. In many cases, not even our mentors had experience with these algorithms; instead, we had to develop theories and experiment in order to achieve the best program possible.

The first part of this challenge came as our lead programmer used the offseason to create a heavily customized implementation of the **positional tracking-based Pure Pursuit algorithm,** common in aerial combat but applied to robotics movement in our autonomous programs. This algorithm assumes that the robot is fastest when moving forward/backward, and runs between points while constantly adjusting its angle to point itself at the next target to maximize efficiency. Midway through the season, we developed an algorithm we believed to be faster, in which the robot takes advantage of its mecanum wheels to **strafe between points** while **several PIDs** - industry-standard proportional-integral-derivative controllers that help bring systems to designated setpoints - adjusted our robot's angle and the positioning of our secondary subsystems. This algorithm granted us a **high degree of control over our robot's motions** at all times and increased efficiency by eliminating the need for any explicit turning and ensuring that all necessary actions were completed simultaneously.



An example of how Pure Pursuit smooths line segments, showing the targets that would theoretically be created with the given linear path assuming a radius of 0.25. The robot smoothly curves between targets..

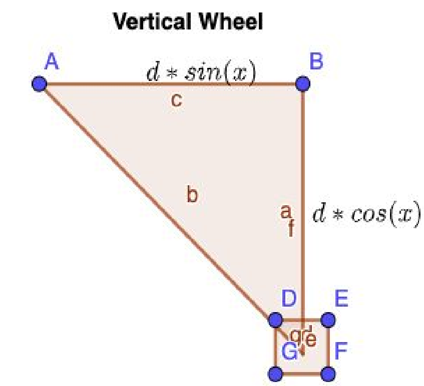
However, these processes relied on **determining our robot's position on the field**. Without a relatively accurate method of doing so, the error that would accumulate would be far too much to allow the many corrects we intended to make - which included measuring velocity to detect when the robot was "stuck" (enabling it to free itself, a capability which proved vital to successful competition

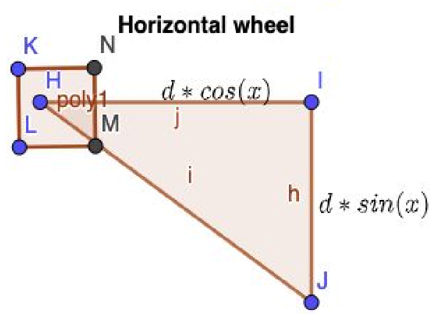


Our odometry module, consisting of two passive omni wheels with encoders to determine how much the robot has moved

performance), and making precise positional corrections. To solve this issue, we attached passive, unpowered wheels to the bottom of our robot, aligning them parallel to the vertical and horizontal axes and measuring their movements with encoders, forming an odometry module.

Because our robot was not always at a zero degree angle, we could not simply convert these encoder readings to distance readings to localize the robot's position. Instead, we **calculated the horizontal and vertical vector components** of each wheel's movements, using our gyro to give angular readings used in the calculation. Using the diagram to the right, the formulae we determined for this calculation were:





$$\Delta x = displacement_{vertical} * sin(\theta)$$

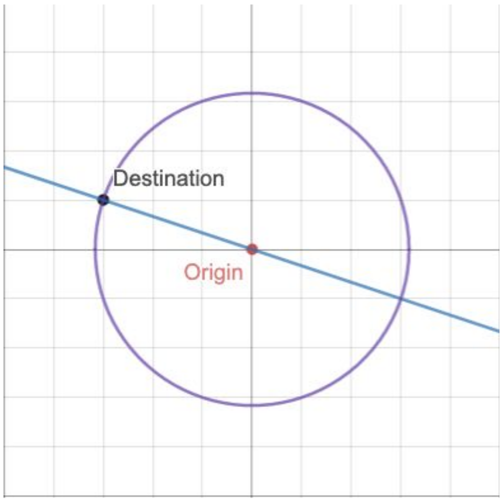
$$+ \; displacement_{horizontal} * cos(\theta)$$

and

$$\Delta y = displacement_{vertical} * cos(\theta)$$

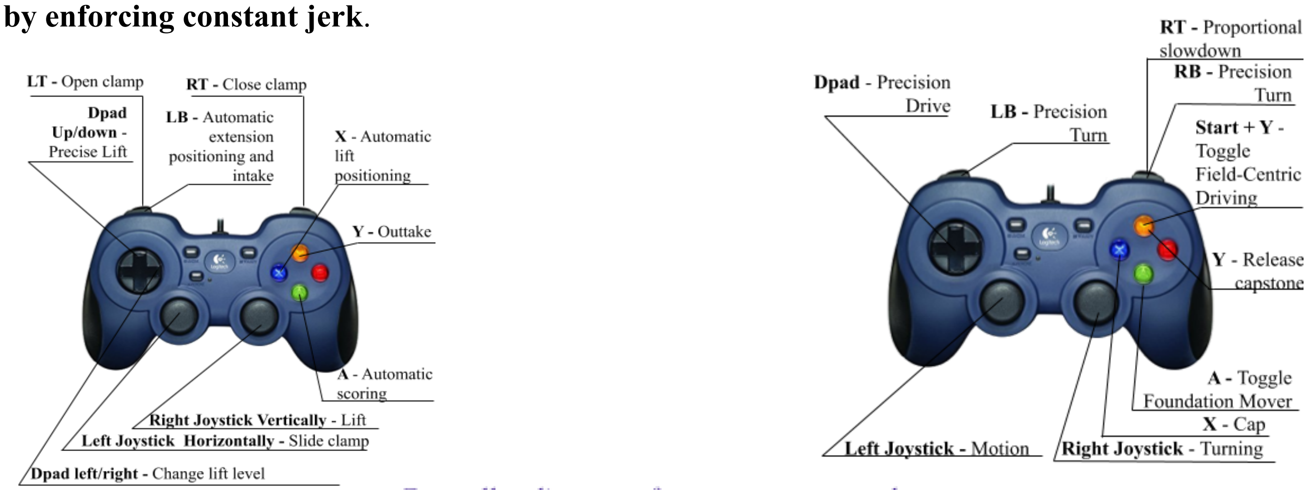
$$+ \; displacement_{horizontal} * sin(\theta) .$$

This solution was mathematically imperfect, though, as it assumes that the robot moves in a linear manner. We determined that it would be far more accurate to **characterize most movements as an arc of a circle**. This solution would still accommodate linear movements, as these can be considered arcs with an angle of zero. After many failed experiments, we concluded that the odometry wheels would report the arc length rather than a linear distance travelled, as we had originally believed. We wanted to create a circle of all possible positions for the robot given our displacement from our original, known point. However, as a circle contains only points with a certain linear distance from a radius, we had to convert this arc length into a linear distance between its endpoints. To do so, we converted the arclength to its corresponding chord length using the formula $c = 2 \times r \times sin(\frac{\theta}{2})$, where θ was the arc angle and r was the circle containing the arc's radius, calculated by inverting the arc length formula, $r = \frac{\frac{360}{\theta} l}{2\pi}$. Using this chord length as the radius of a new circle centered around our known field location would yield a circle of all possible new locations for our robot. We also postulated that our strafe angle could be represented as $tan^{-1}(\Delta y,\ \Delta x)$ based on the changes in our odometry wheels' encoders. Combining the strafe angle with a gyro reading allowed us to find our exact angle of movement; by drawing a line at that angle crossing our old, known location, we could find two intersections with the circle, one of which would represent our robot's location. Using the "imperfect" method to estimate our location, we determine which of these potential points was closer to the estimate, allowing us to calculate our position.



A model of the attempt at odometry math. An exact match was achieved, indicating that the intersection of a line and a circle defined as those above would approximately equal our robot's new position

Another central goal of our programming subteam was to **automate driver controls** to make sure that our TeleOp period was as easy for drivers and efficient as possible. Our **mecanum drivetrain enables omnidirectional movement**, of which our drivers can take advantage of using **multiple driving modes** - though uncommonly used, our drivers could, for example, force the robot to move at the absolute angle of the joystick regardless of its field angle. We also **automated the lift alignment with our stack**, **automated the intaking process, and smoothened our lift movements by enforcing constant jerk**.



Controller diagrams for our two gamepads

As all but one member of our programming team consisted of **first-year members**, few of them had experience with these rather complex implementations. We therefore ensured throughout the year that all algorithms were **derived and conceptually proven** to the entire subteam. We have also been largely successful in teaching our members by allowing them to teach others; our new members **actively participate in teaching software concepts to other teams, improving our own team's understanding of these concepts**. Throughout the year, we distributed programming manuals at competitions to help spread programming knowledge throughout our region.

Our lead programmer, Miles, helping a programmer on a rookie team during our league scrimmage, with one of the programming manuals we distributed.

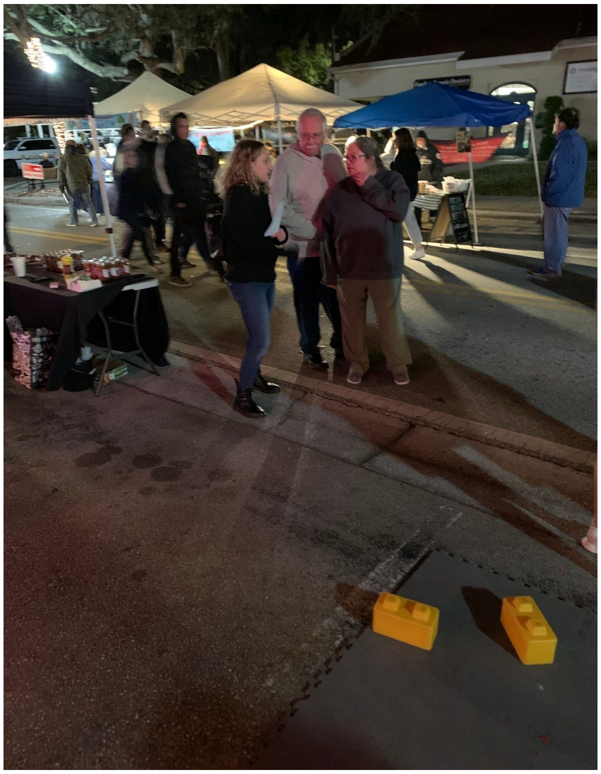
While our constant focus on experimenting with interesting and complex control algorithms required an intensive time commitment, we were able to achieve a very successful programming subteam throughout the season, helping us successfully navigate this year's game and earning us **3rd place for the Control Award at the Florida Championship**, the main award for innovation in software design. Software experimentation this year was a major learning experience for our team, and we plan to continue to expand and spread this learning across our club and the broader STEM community.

Outreach

As a STEM program that relies on the generosity of sponsors and donors like yourself, we enjoy giving back to the community that continuously gives so much to us. This season, our team had many memorable outreach events such as a **demo at Glazers Children's Museums in Tampa, introducing our program to younger students at more than ten schools across the community, visiting sponsors and local businesses, and spreading the word about our team and FIRST at community events such as Third Friday in Safety Harbo**r.

This season, we attended **a demo with other teams from our league at the Glaziers Children's Museum in Tampa** to showcase our robot and its documentation in our engineering notebook. We presented our robot and notebook to various families and informed them about the benefits of STEM programs such as FIRST. Skills that our team demonstrated included **driving, engineering, notebooking, CAD, programming, and social media documentation**. They demonstrated them by explaining how those skills were used to perfect and improve the robot presented to them. Members also learned valuable presentation and speech skills that will aid them in interviews and presentations in the future. By pitching robotics and the ideals of FIRST to the community they are able to get valuable practice and hone these skills at

Our robot being demonstrated to visitors to the Glazer Children's Museum a young age. Families were introduced to the idea of FIRST Lego League teams so their children can be involved in STEM and FIRST programs before highschool.



One of our team's first-year members introducing our program to a visitor to our booth during one of Safety Harbor's monthly Third Friday events

This year our team did many **community outreach events** such as **Third Friday's in Safety Harbor and visiting Raytheon**. Raytheon, a long time sponsor of ours, got to see our appreciation of all their support throughout the years when we went to their office to demonstrate and explain the technical portions of the robots and allowed employees to drive and observe the robot. Raytheon and its employees have been an integral part of our robotics journey with generous donations of time and money. Safety Harbor's Third Friday's events have allowed our team to generate connections with the public and obtain future outreach events. This year, during Third Friday, we were able to get the attention of Mastercut Tool Corp. They allowed us to tour their Safety Harbor facility, where we also demonstrated one of our club's robots and gave employees the opportunity to drive it.

Our team has been able to generate **a global presence by using social media**. This year our team ventured into using our social media resources to spread word about our team, robotics, FIRST, and our sponsors. We have been reached out to by teams from Texas, New Jersey and Brazil and have worked with them when they had questions or needed advice.

Accomplishments

Even though our team this year was composed mostly of first year members, we were able to achieve several impressive accomplishments. These accomplishments include winning **3rd for the software-based Control Award** at the Florida State Championship, and, at our League Championship, **2nd place for Inspire**, the award granted to the team who best exemplifies the ideology of FIRST, 1st place for Connect, 2nd Innovate, 2nd Design, and 1st Compass at our League Championship, based on our extensive efforts to spread STEM across our community and commitment to uniqueness and elegance in design. Additionally, at our League Championship, we were fortunate enough to be selected by our sister team to join their alliance in the elimination matches; **this alliance would win the League Championship**. These accomplishments granted our team the opportunity to **attend the Florida State Championship**.

Although we did not qualify for the World Championship, our team was able to grow from this journey. We **connected with hundreds of students and teams** to help the many rookie teams this year familiarize themselves with FIRST and extend our passion for robotics to younger students. Furthermore, we recognize more personally the extent to which teamwork is necessary to make a robotics team operate functionally. Despite the challenges we faced throughout the year, we are honored to have learned so much, experienced the state championship, and spread our program across our community.

Our team pictured with 7321 Charlotte Surge and sister team 3101 Boom Bots, the winning alliance of our region's League Championship