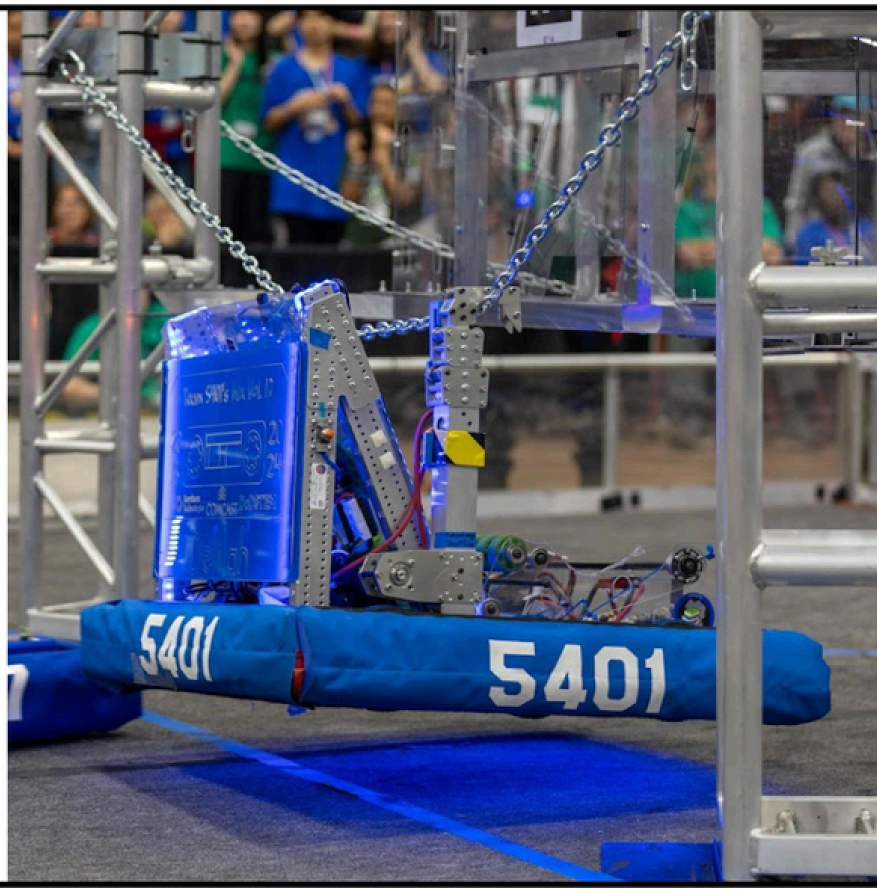
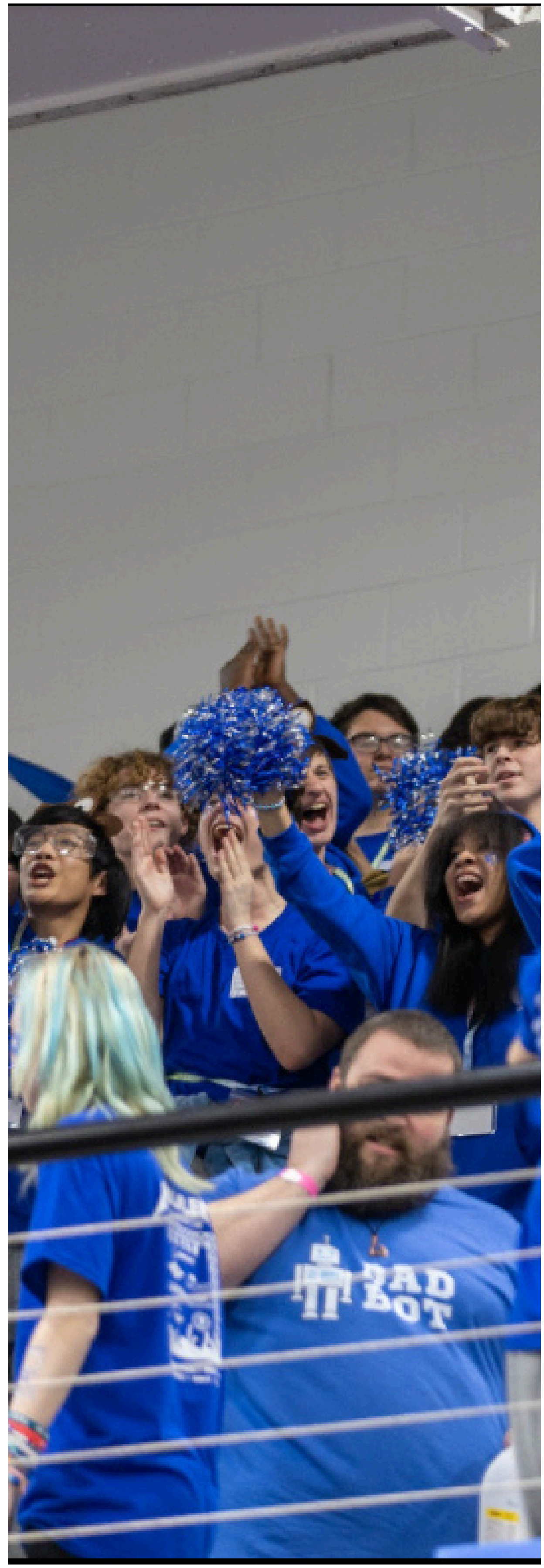


Team 5401

Technical Summary

2024-2025	Fightin' Robotic Owls	REEFSCAPE

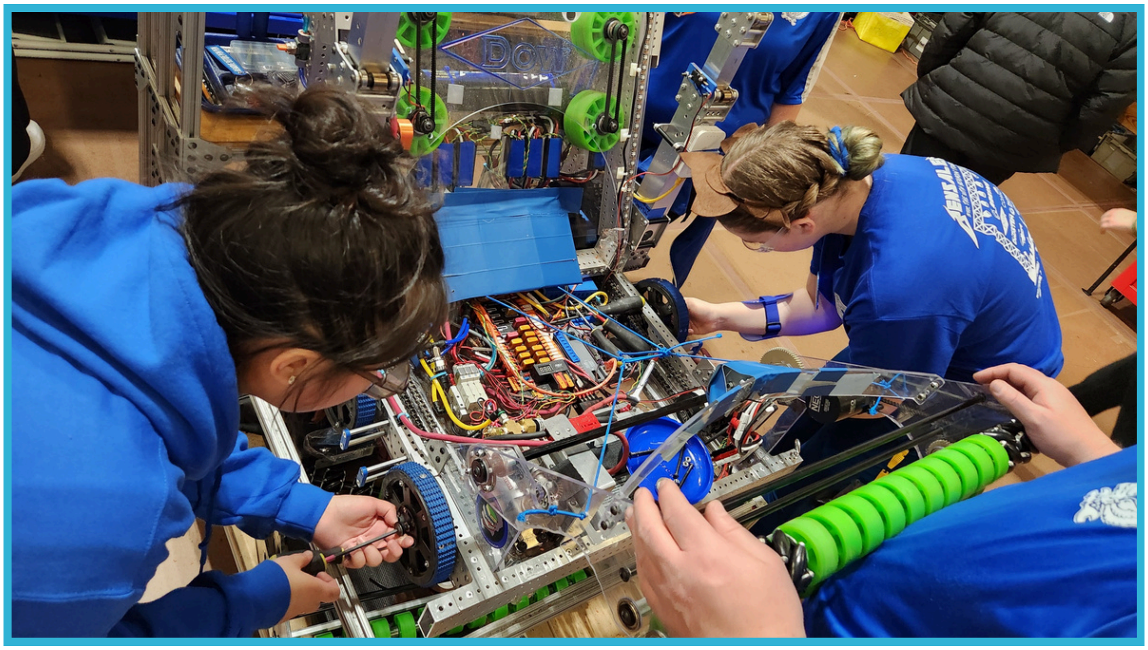
TABLE OF CONTENTS



1. Introduction

Team 5401, the Bensalem High School Fightin' Robotic Owls, enthusiastically returns for the 2025 season of the FIRST Robotics Competition, REEFSCAPE℠, presented by Haas. For a second straight year, our team has had a significant membership spike, representing nearly half of our roster. With this comes the challenge of engaging many inexperienced students with our design process and the demands of build season.

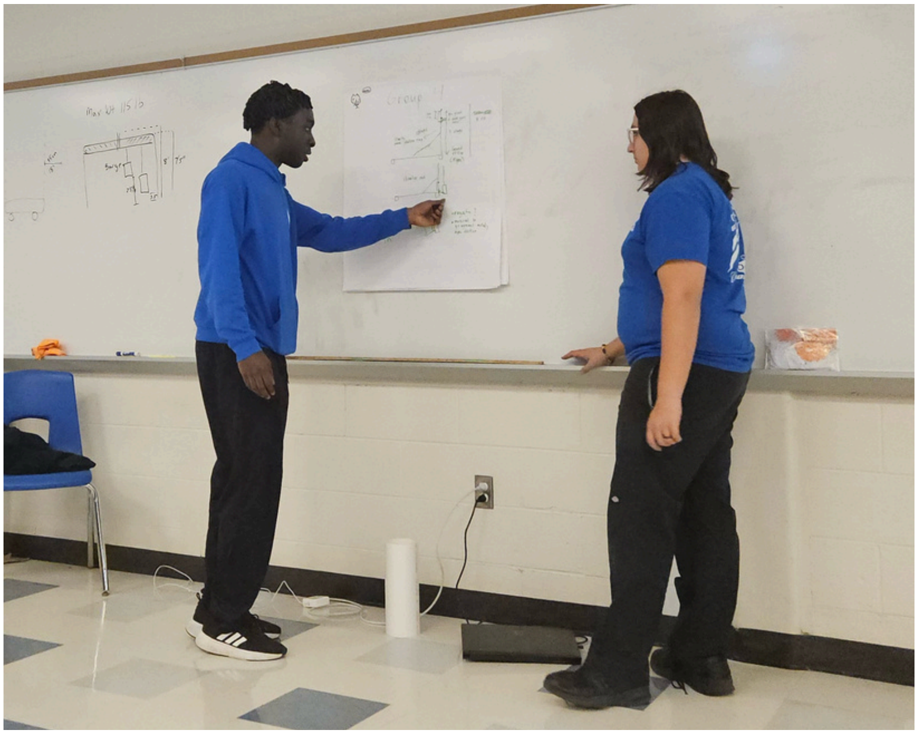
This season, our team is infused with a renewed sense of energy and determination, blending the fresh perspectives of our newcomers with the seasoned expertise of our veterans. With unity at our core, we are poised to tackle the challenges of REEFSCAPE℠ with creativity, teamwork, and innovation. Together, the Fightin' Robotic Owls are ready to spread our wings and soar to new heights, embodying the spirit of FIRST Robotics Competition as we strive for excellence in all our endeavors.



2. Kickoff Weekend

On Saturday, January 6th, Team 5401 gathered in Bensalem High School to watch the REEFSCAPE℠ game release video. We expect team members to take their own notes on the video and begin brainstorming ideas individually. We immediately dive into the released Game Manual and discuss the rules and possibilities for our robot. Saturday featured multiple breakout rooms, where groups of around 10 students began strategy discussions. The main debates this year were over algae versus coral pick-up and whether deep cage was worth it. The meeting is a short 4 hours, but marks the beginning of our busy season. Between Saturday night and Sunday morning, students continued their discussion online and read over the game manual again. By Sunday morning, our strategy for the season was decided.

The next day, we met at the high school from 9-4, with the goal of answering the question How? We broke into groups and discussed every aspect of design one at a time: infeed, shooter, climbing, and more. Our team gathered after every breakout session to review, critique, and expand upon each group’s design. Mentors were able to provide constructive criticism to ideas and to play “devil’s advocate” to help students clearly deliver their ideas and ensure the viability of these plans. By the end of this weekend, our outline for the season was nearly complete. We immediately started our build season schedule the next day and got to work!



3. Robot Design

3.1 Drive Train

3.1.1 Design Phase One

This season we made a different decision with our drivebase than usual at kickoff, choosing to use swerve drive. Historically, our team has used West Coast Drive, using three wheels on each side powered by four motors to take advantage of the enhanced torque provided by the system. However, this year we looked at the game and decided that swerve drive would be the optimal choice of drivebase, allowing us to navigate around the field efficiently and rotate more easily. We looked at various modules, but settled upon the MK4n from Swerve Drive Specialties. This gave us more room down the center of our robot on one side, which we believed could help us fit the other subsystems we discussed on kickoff.

3.1.2 Design Phase Two

We decided to power the drivebase with Kraken X60s in order to give us both high speed and torque. Along with that, we initially chose to fit the robot in a 30” x 30” robot perimeter to keep all sides even with swerve’s exceptional rotational abilities, as well as give us the most room to work within the robot as possible.

3.1.3 Design Phase Three

Upon further review of the field and what we wanted to do in matches, we made the decision to shorten the width of our robot and extend our length. This took our robot perimeter from 30” x 30” to 28” x 32.” With this extended length, we were able to increase the max height of our elevator. With the shortened width we made ourselves able to safely move between two deep cages, increasing our overall mobility throughout each match.

3.2 Elevator

3.2.1 Design Phase One

Exiting kickoff, the team knew we wanted three things out of the elevator: enable us to score at every level of the reef, contain three stages and a carriage, and pivot upwards at the start of the match. Combining a three-stage elevator with the ability to pivot upwards at the start of the match would allow us to make our elevator reach heights otherwise unattainable, as we can optimize the starting size limits to make it taller overall. We viewed it as a solid way to score at every level of the reef, as it would let us extend tall enough to reach all the way up to L4. We set it up using the Andymark Compact Elevator bearing blocks for the three main stages, and the Swerve Drive Specialties Billet Elevator Kit bearing blocks on our carriage. The mechanism is driven by a combination of chain and sprockets and rope and pulleys. A sprocket is placed at the bottom of the elevator's first stage, driven by a MAXPlanetary and MAX 90 Degree Gearbox, and turns a #25 chain which is hooked onto the second stage. The rest of the stages of the elevator move at the same time due to our system of rope and pulleys, as there is no option for the rope other than to shift around our tensioning and thereby lifting or lowering the stages. The system overall gives us great height for our end effector, although the way the elevator actually pivots would be a major challenge for us to tackle.

3.2.2 Design Phase Two

When we first discussed the elevator pivoting, many wanted us to motorize it. However, we looked at many different options to lift it up, and decided that using gas springs would be our best bet. We chose to use gas springs because we found they were well equipped to handle concerns we had about shock absorption, and were overall better than motors as we wouldn't have to worry about the force that the weight of the elevator would be putting on a motor. After lots of digital prototyping using CAD software, we found suitable gas springs to lift the elevator, and one 30 lb. gas spring is mounted on each side of the robot's chassis, connecting to the first stage of the elevator through a plate. In order to hold down the elevator, we have 3D printed blocks between stages that are put in tension by a rope connecting them to the drivebase. When the elevator lifts for the first time in the match, enough space is made for the blocks to slide through, allowing the gas springs to push our elevator up.

3.2.3 Design Phase Three

As we neared our competitions, we found that our robot was decently heavy. In order to fix that problem we've started looking into cheesing the elevator out, and currently have models for all three stages cut out with holes to reduce the weight of the elevator along with the entire first stage's cheesed versions cut. We don't currently have the cheesed elevator on our robot, however we intend to cut the remaining pieces and implement it before our next competition.

3.3 Manipulator

3.3.1 Design Phase One

The first design phase of our end effector consisted of testing the manipulability of both game pieces: the algae and coral. We found that Compliant Wheels worked well with both of the game pieces. We then decided to test different durometer ratings of compliant wheels, but anything with a rating of 50A and above didn't seem to form well with the coral. We decided to go with a 35A durometer rating due to their capability to form around the coral without the consequence of losing grip on the algae, giving Leviathan a better hold of both pieces. We initially went with a hook-like end effector that would collect the algae with two sets of wheels above the coral, having the bottom set also be the top wheels to pull in the coral. The hook-like infeed was set up vertically on our elevator. This concept saved space making one end effector to grasp both game pieces, while taking up much more room than we had been hoping for. We ultimately decided that one end effector to collect both game pieces was simply too large to be effective.

3.3.2 Design Phase Two

Sticking with wheel choice, we then went with a much slimmer design, having our end effector horizontal on our elevator and made slim enough vertically to fit closely to the coral. This was a decision made based on our discovery that even with its spherical shape due to its compressibility it can be picked up without going the diameter of the ball both horizontally and vertically. This end effector had great control over algae, but we found its control of coral was lacking. The back row of wheels simply could not come close enough to the coral station to be effective, so we needed a new approach.

3.3.3 Design Phase Three

We needed a new idea. We wanted to keep its slimmed down design as well as relative shape. Then there it was, a pivoting mechanism that pinches in the two front sets of wheels to fit to coral. In order to have both the front sets of wheels be driven by two motors indirectly and the same axles directly drive the pinching motion, we decided on bearing bore pulleys. These would be indirectly driven by the backmost motors via pulleys and further driving the front most wheels via pulleys. This was our final design, after lots of both physical as well as digital prototyping we had the manipulator leviathan wields.

3.4 Climber (Not in use during Hatboro-Horsham Event

3.4.1 Design Phase One

Coming out of kickoff, we knew we wanted to spend the endgame climbing on the deep cage, but we weren't entirely sure how we wanted to achieve that. The common theme between the various ideas we came up with at kickoff was using some sort of mechanism to grab onto the cage from the inside, and then pull the rest of our robot to the cage. The first idea that we spent time on utilized two hooks that would make it in the cage, and then be rotated outwards to latch onto the cage. From there the system the hooks were on would be brought into the robot, allowing us to get the deep climb points. However, as more time went on we found that the design didn't work well with our elevator system, which eventually led us to look into Penn State's version of a deep cage climber.

3.4.2 Design Phase Two

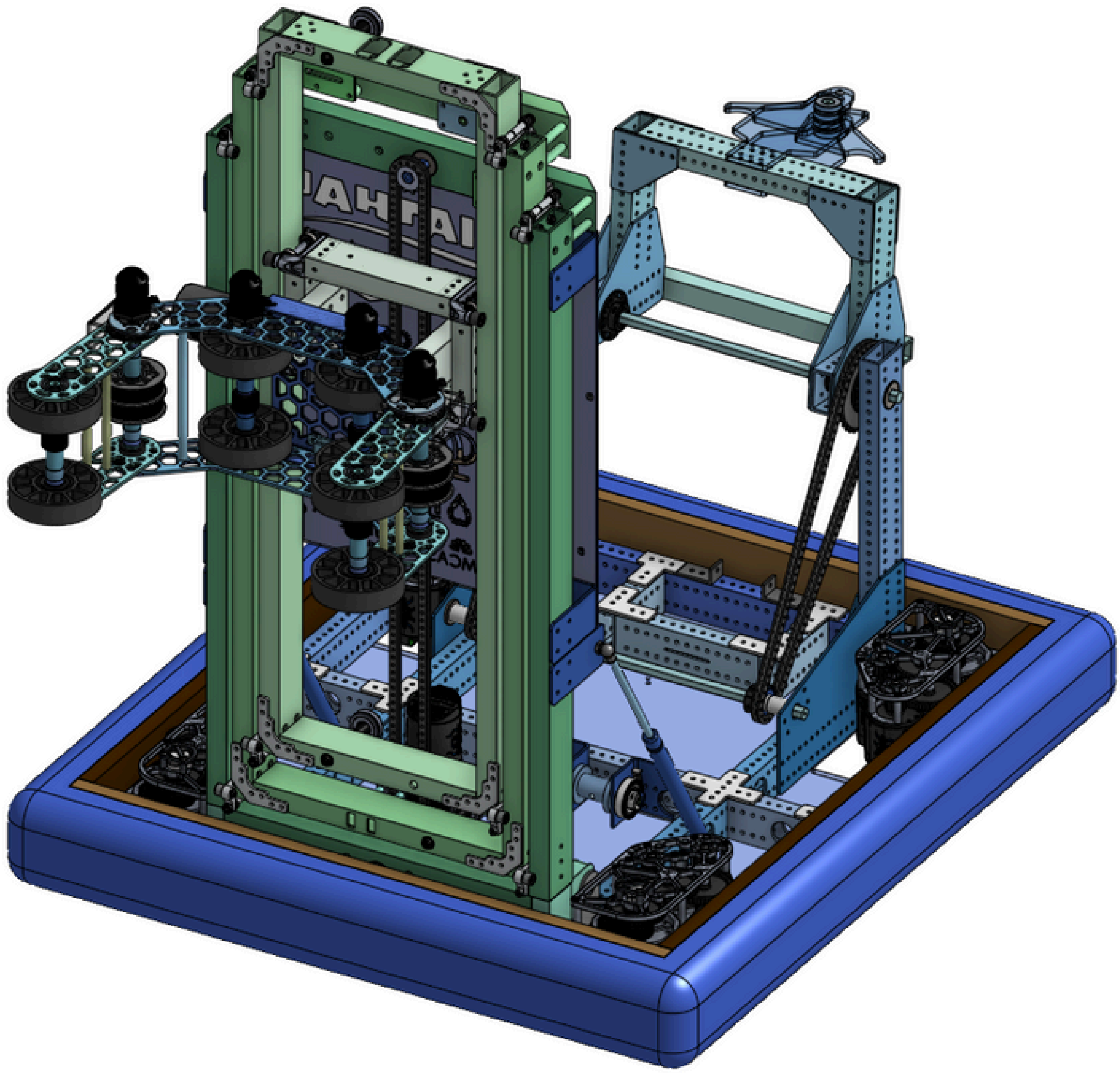
The next climber that we tried working on was one inspired by the Penn State Robot in 3 Days team. The design involved positioning the cage inside the robot and then pushing down into it, with the cage passing through a hole in our belly pan. This required us to significantly adjust our design, particularly through edits to our drivebase. The most significant of these was removing most of the belly pan, which forced us to reposition multiple electronics. We found spots for a few things, but before getting too far into the design the team looked for a different climber. This led us to the climber concept we ended up sticking with, that being one based off of Team 118's Everybot.

3.4.3 Design Phase Three

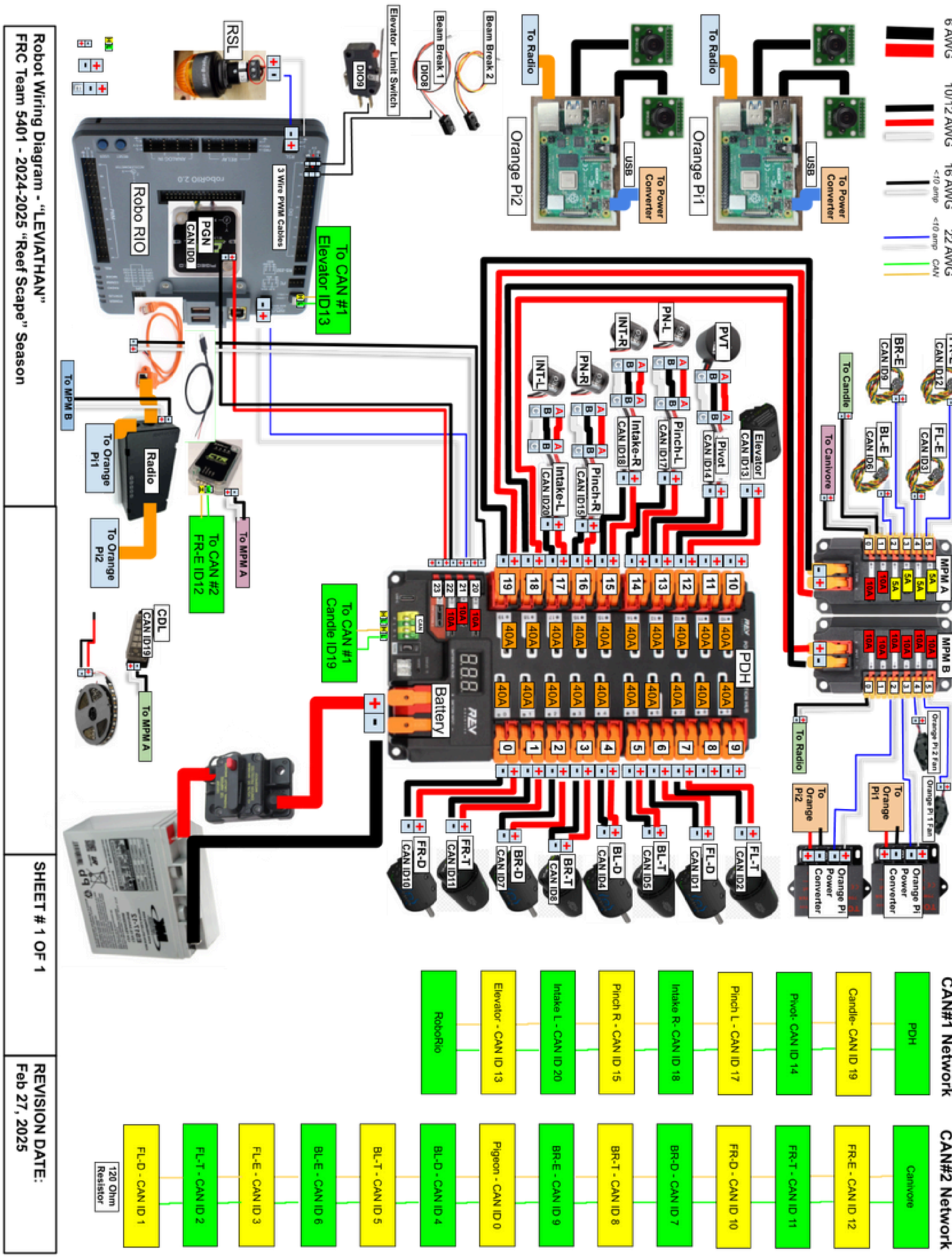
Our climbing mechanism features a barb sourced from Team 118's Everybot, which was modified to fit our robot better. When the climber is pushed into the cage, the inner latching parts of the barb allow the cage to enter the robot. Then, the system pivots inwards, and a locking system of rubber bands and zipties prevents the robot from falling off of the cage, and the motion brings our robot off of the ground. The ends of the barb are mounted on the sides of a tube, allowing us to connect the climber to two parts of our robot's chassis and increase the structural integrity. This was important because our robot is significantly front-heavy, meaning the climber needs the extra support. It also adds more weight to the back than just attaching it at one point, allowing us to balance out the aforementioned weight in the front. The climber was initially driven by a chain placed further down the robot, but we decided to drive it directly at the top by mounting a MAXPlanetary gearbox on one of the tubes that mounts the mechanism to the chassis. This allowed us to centralize more of the weight being used on the robot towards the back and balance out the center of mass more thoroughly.

3.5 Technical Drawings

CAD Rendering



Wiring Diagram



4. Software and Controls

4.1 FRC Architecture and Object Oriented Programming

Team 5401, like many other teams, primarily utilizes the Java programming language. Java provides us the ability to match objects found in the real world, with objects directly embedded into our code.

Code is split into Subsystems and Commands. Subsystems mimic the physical parts of the robot, while commands execute actions that the physical robot can perform. The Robot and RobotContainer classes serve to loop the code of our robot utilizing the Scheduler class built into the FRC Architecture. With these loops, we are able to map a button to a given command which can be executed in Tele-Op and the same commands can be used in autonomous periods of matches as well. This command system has allowed us to do on the fly path generation bound to a single button on the driver controller. For example driving right over the station to pick up the note.

4.2 Collaborative Work Environment

The software team for Team 5401 have a weekly status meeting to discuss achievements from the previous week and goals for the upcoming week. We run a modified version of SCRUM with daily standup meetings asking for blockers & questions. Meetings are often organized to discuss the general logic implementation of each individual Subsystem. Outside of meetings, programmers may work individually or in a team depending on the project currently being worked on. We practice paired programming where the 'rider' and 'driver' alternate throughout the meeting.

The following apps are used to communicate and organize the software team:

Slack

GitHub

Google Drive

Slack
This application is mainly used for communication, such as writing down goals and reminders. Slack has the GitHub integration enabled and allows automatic messages to be sent when Pull Requests (PRs) are open and are merged.

GitHub
This application is used to store the team's code online as a code repository. As a result, any computer can pull the code from GitHub and edit it. In addition, GitHub offers the ability to "branch" code which creates a copy of the current working code which allows experimental code to be created and tested without overwriting the current code that works. If the experimental code fails, the branch can be abandoned without modifying the working code. If the experimental code works, the code can then be merged into working code. This year, we've adapted a "Staging" Branch for any new in and in progress testing, keeping our production branch, or main branch, free from error.

GitHub Projects
A Kanban board and issue tracking system which exists outside of a single repository. This allows for us to have a single board to create "issues", or to-do items, for tracking across multiple code bases/projects.

GitHub Actions/Pages
GHA is a cloud-based CI/CD pipeline runner available to all public and private repositories. We use GitHub pages to host our team wiki site which has documentation from subteams compiled into a single space.

Google Drive
Google Drive is utilized to share other files that are not code. Code documentation and block diagrams are created and kept in Google Slides. Mechanical and software teams share a Google sheet detailing all the PWM, sensor, and pneumatic solenoid channels for the robot. Controller mappings are documented and stored on Google Drive as well.

4.3 Implementing the Programming Process

4.3.1 Identifying the Problem & Research

Projects are either self-identified from the programming team or given to us by another sub-team; such as scouting or business. Once a problem is found, research is done to see if another FRC team or product has solved it. If the search is not fruitful, additional research is done into tooling & frameworks needed to solve the problem, and many forms of training are offered to the programmer.

4.3.2 Designing/Drafting the Solution

After research is completed, High-Fidelity mockups are made in Figma for UIs and a class diagram is made for backend logic. The software team then converts the mock ups and class diagrams into GitHub Project issues to assign to programmers. Certain issues are handled individually and others are paired depending on difficulty. Since the programming team sits together in the same room lots of collaboration happens regardless of pairing. Coding branches are made for specific purposes on a case-by-case basis. For example, testing Shuffleboard, Vision, and Autonomous for the first time typically requires its own branch before it can be integrated into the finished product. This also allows us to have multiple programmers work on different aspects of the project at the same time.

4.3.3 Testing and Revising

When an issue is completed a Pull Request(PR) is opened which has a premade template the programmer must fill out like the example below.

Description

Finished Drivebase Infeed, Shooter, and Climber, after validating testing.

Related Issue

#3
#4
#7
#13
#15
#16

Motivation and Context

- The following code was tested on the robot and verified for functionality. All of the code is functional and if any changes are needed they are minimal.

Changes Made

Added the drivebase, infeed, shooter, and climber (Mk 1) subsystems. Commands for each subsystem were also added.

How to Test

-Commands and buttons in robot container File

Checklist

- [✅] The code follows the project's coding guidelines
- [✅] All existing tests pass successfully
- ☐ New tests have been added to cover the changes (if applicable)
- ☐ Documentation has been updated to reflect the changes (if applicable)

Additional Notes

4.4 Teaching New Programmers

Every year, several rookie programmers join the team with little to no experience in writing code for the robot. The Programming Lead assumed the responsibility of teaching any and all incoming members with help of the programming mentor where needed.

A lesson plan was developed for the purpose of teaching incoming (and returning) members. The lesson plans varied from a wide-array of disciplines, with rookies becoming well versed in basic Java, FRC Control Systems, and fundamental software (like VSCode & Github) before being sorted into the “clique” of their choosing. Programmers were able to choose between learning more advanced Java with Robot Code or exciting Mobile App Architecture with Android Studio with Kotlin. This year we have looked into web based ventures with GO and JS

4.5 Human Machine Interface

The Team Utilizes two Xbox controllers for ease of learning, as many people have used an Xbox controller or similar. This year we have decided to automate as much as possible, even for the Tele-Op Period. Buttons are bound to Auto Commands for not only the Operator but Driver too.

The Operator has controls for the Elevator, and Manipulator. The Operator has set points for moving the Elevator, and set Velocity for the Manipulator so the Operator does not need to play it by ear. The Driver has a few commands, the main one being the drive controls. However, the driver can also change the lights. However, the new control for the Driver is the ability to generate a path right to the Reef from anywhere on the field, which reduces the room for human error inside of the robot. The Driver also has the ability to align with the reef for quick and near error free shooting.

4.6 Scouting App

The FRO Scouting App was developed using Java and XML in Android Studio. The app is optimized to run on a Samsung Galaxy S9 Tablet running Android 12 (API 31). This application can be used to scout any game of any year as it is entirely customizable, allowing for developers to easily set up and create the layout with modular components, based on the scoring guidelines that they find to be the most crucial that year. The user inputs data through a variety of components, then gets exported into a JSON file on the tablet. Then the tablet is plugged into a laptop, where a desktop scouting application is able to pull the JSON files from the tablets and synchronize the data in Microsoft Excel. It is then exported to Tableau for our scouting team to analyze and create graphs.

4.8 Autonomous Features

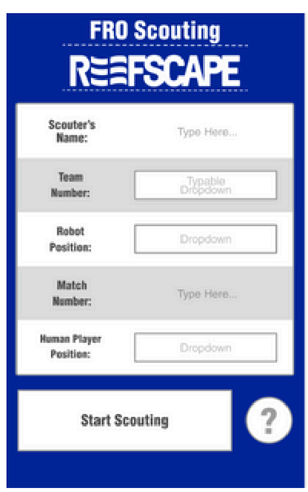
Our Autonomous has taken a major leap from last year, with even further improvements in the works. In the past we have used a very crude and rudimentary system for driving, simply checking the encoder value to see if we are there yet. This year as a team we have decided to step up not only our 15 second Auto period but the entire match. This includes a set of new sensors, including limit switches and even some A.I for vision processing.

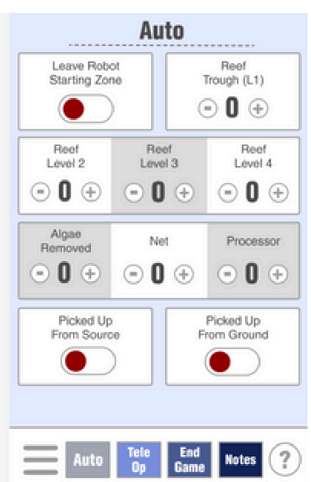
The primary digital sensor we use on the robot is limit switches. We use this for automatically stopping our infeed once a note is detected, and stopping the climber once it has reached full contraction. This allows the Operator to handle less and less input, allowing them to focus on the next action before the current one is done.

The Operator also has some Analog sensors. These include the integrated encoder inside the Rev NEO motors that we use. We use these integrated sensors for both the Infeed and Shooter, in quite different ways. We use a PID Controller for the infeed for setting its position, allowing the Operator to push a button and watch as the Elevator pops into position. We use a Similar control Scheme for the Manipulator, allowing it to spin up to speed, as well as pivot to a position all at once.

The Driver has some new and exciting Autonomous features. The first of which is Auto-Alignment to an April Tag. This allows the driver to push and hold a button, and watch the robot align itself according to a provided distance and angle. Secondly, our “On-The-Fly” path generation allows the Driver to hit a button, and watch the robot drive right over to the Reef. These two capables allow the robot to nearly drive itself to and back from the station.

Our primary goal for Leviathan this year was to play not only to the Drivers/Operator Strength but the Robot itself. Robots are good at aligning, with a very small margin of error, but they are not capable of planning ahead, and this is where the human comes in. While yes, in theory the robot is capable of operating completely on its own, it is enhanced by our human minds operating the robot. This theory allows for a perfect combination between human and robot-operated control.



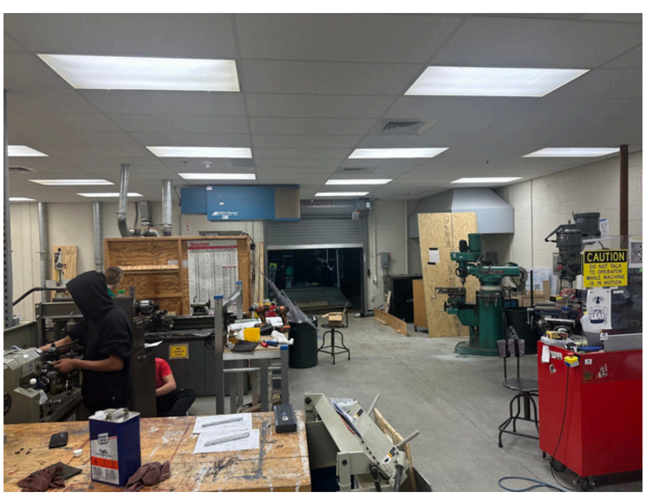


5. Manufacturing

The STEM program at Bensalem High School, significantly enhanced by a newly renovated technical education facility in 2017, has seen all manufacturing of Leviathan performed in-house by our student-led manufacturing team. This year, alongside our broader manufacturing activities, a few members received training on our CNC router. With only three team members proficient in its use, the CNC router has nevertheless played a key role in our production process. It has been essential for creating specific complex components of Leviathan, including the Aluminum plates for the infeed, all of our gussets and brackets, the drive base belly pan, and the acrylic backplate. Each of these parts, critical to the robot's functionality, showcases the precision and versatility of the CNC router, despite its limited operator base.

In parallel with the CNC router work, our team has learned and used other equipment. 7 rookies were trained on a modern milling machine with digital measurement and calculation abilities, and we also utilized a set of two lathes. An older model milling machine was revived in our previous season and further repaired this season, offering an experience in traditional machining techniques, emphasizing manual skills and old-school methods. This diverse approach to manufacturing, including the selective but impactful use of the CNC router, reflects our team's commitment to developing a wide range of skills and producing high-quality components for Leviathan.

To complement these efforts, we've integrated multiple 3D printers into our production pipeline, including a Makerbot Replicator+, an Ender 3D Pro, and a Markforged Onyx Printer, enabling the creation of complex parts from strong, lightweight materials. This blend of 3D printing and precise (though selectively used) CNC routing has equipped our manufacturing sub-team to meet any challenge, ready to manufacture any part needed with innovation and meticulous attention to detail.



6. Practice Field

After Kick-Off Weekend, we started building our field with majority-recycled wooden and cardboard elements to assist prototyping, as well as give the drive team a practice field on which to hone their skills. The assembly of the practice field this year was an incredible opportunity to get as many of our rookie students involved as possible and give them hands-on experience. In the weeks before Kickoff, we had an “Intro to Build Season” day for our new members. They learned basic woodshop and an overview of prototyping and its importance. This helped introduce them to basic engineering concepts to prepare them for going into the season and allow them to help build the field and prototype.

This year, in efforts to expedite the process of field building, we created 3 sections. The first section was tasked with printing out all of the blueprints and organizing them by subassemblies. They then were able to calculate how much of every piece needed so they could send our mentor a bill of any needed materials to buy so we could start construction. The next section was tasked with cutting all the 2x4 pieces of wood to length, all the basic shapes out of ½” Plywood. The last section took all big pieces with special features and CAMed them and ran them on the CNC. These pieces include for example the stage main plates. These three groups working together allowed us to complete our field construction in record time to allow for fast prototyping and drive practice earlier.

The process of constructing both the reef and the barge was challenging and often repetitive, with a few setbacks along the way. The initial construction of the first reef was relatively straightforward; however, the majority of the difficulties stemmed from management issues, such as keeping track of materials and managing the work being done. While smaller pieces were easy to track by bundling them together and labeling them with paper, the larger pieces posed more significant challenges. Ensuring proper measurements and involving the freshmen in the process became a bit problematic. We had a hard time trying to involve them but not to hinder their learning.

Our field team consisted of 3 upperclassmen members in charge, overseeing approximately twelve new members. The task of teaching the freshmen how to use tools and take accurate measurements was a bit hard to solve, especially given that some had never used a drill before. Determining how to balance teaching responsibilities and provide assistance was a major hurdle.

To address this, we divided the freshmen into smaller groups of four. Each group was assigned a piece of paper outlining the basic steps they needed to follow. This approach allowed us to give focused instruction while still maintaining oversight. Although we did not want to micromanage the freshmen, all three experienced members circulated among the groups, offering guidance and troubleshooting when problems arose. Our approach was to empower the freshmen to take initiative, but to be available for support when necessary.

Once all the wood was cut to the appropriate lengths, we proceeded with the field construction. This phase was relatively straightforward, as the freshmen, under the guidance of the experienced members and with the assistance of the instruction manual, were able to learn how to use a drill and interpret the instructions. However, for the more complex components, the older members took charge. For instance, while constructing the feeder was manageable, the most challenging aspect was attaching it to the actual field. Despite this difficulty, the overall process remained relatively simple.

The most significant challenge we encountered was the construction of the barge. We had to create it from scratch, from CADing and building to cutting the necessary components. Despite the numerous challenges, we successfully constructed a fully functional, 1:1 scale barge weighing roughly one ton. While the weight itself was considerable, it was not the most problematic aspect of the project.

The primary difficulty lay in the complexity of the construction process. It required an immense amount of time and effort. One meeting was dedicated solely to the assembly of the barge, and an additional two meetings were spent cutting and preparing the pieces. The meticulous nature of the work, coupled with the large scale and weight of the barge, made it a daunting task for the team. Each step involved careful attention to detail, coordination, and problem-solving, particularly when it came to ensuring the various components fit together seamlessly. Ultimately, the process proved to be a test of both patience and perseverance for all involved.

7. Conclusion

Team 5401 takes great pride in the creation of our robot, which embodies a sense of accomplishment for the entire team. From the outset of Kickoff weekend, we were determined to develop a competitive and robust robot despite the challenges of a young team and adopting a new drivebase. We are excited to continue innovating and learning as a team, providing Bensalem students with an accessible STEM experience in the process. This season, we are ready to dive deep and field a competitive robot!


TEAM
5401