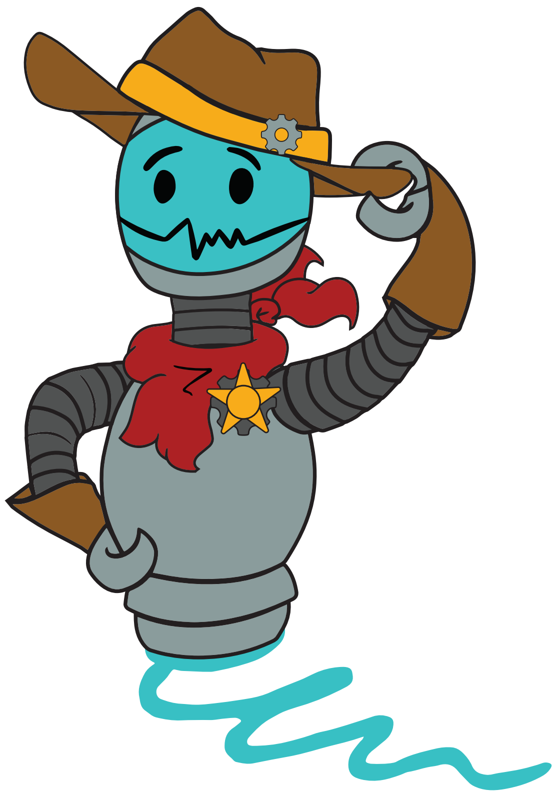
HOWDY BOTS

FRC #6377



TECHNICAL DOCUMENT 2025

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GAME ANALYSIS

Game Synopsis

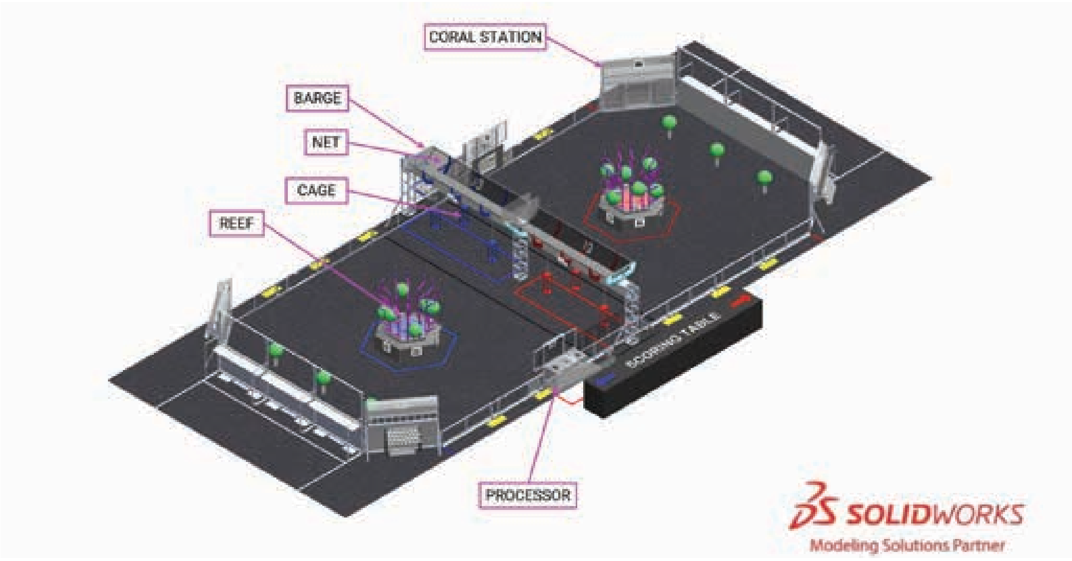
In the 2025 game, REEFSCAPE presented by Haas, two competing alliances are invited to score Coral, harvest Algae, and attach to the Barge before time runs out.

Coral are 4"PVC pipes that can be collected from the alliance's source or from the field. Robots can score them onto L1, L2, L3, or L4 of their Reef. If an Alliance scores 5 Coral on each and every level, the earn the Coral Ranking Point.

Algae are 16.25" diameter rubber playground balls that must be harvested from the Reef. Robots can score Algae into their Processor or straight into their Barge. Algae played in the Processor is fed to the opposing alliances Human Player for a chance for them to throw the Algae into the Barge.

The Reef and Processor are both on the alliance's side of the field. Once two Algae are played in each Processor, each alliance earn a Cooperation Bonus.

Towards the end of the match, robots can climb to their Barge by hanging off of Shallow and Deep Cages. Alliances with 14 Barge points earn the Barge Ranking Point.



Robot Specifications

After a deeper analysis on the game, we collaborated on making the main decisions for the robot design. We began with discussing WHAT our robot can do, not HOW. Next, we sorted each aspect with either a must do, should do, or could do and identified a few non-negotiable.

Lastly, we made a list of questions to answer later in prototyping

NONNEGOTIABLE

- No Stuck Game Piece
- Sub 15s Battery and Bumper Changes
- Swerve Code works
- Human Player makes Algae into the Barge

PRIORITIES

MUST

- Score Coral L1-4
- Remove Algae
- Leave in Auto
- Score Preload
- Coral Ground Intake
- Precision Mode
- Auto Alignment

SHOULD

- Process Algae
- Deep Climb
- Score +1 Coral in Auto

COULD

- Fit back in Frame Perimeter
- Object Detection in Auto

OPEN QUESTIONS

- Can we push Algae into Processor?
- How hard is it to score on L4 verses L3?
- How hard is it to Deep climb versus a Shallow?
- How many Algae reasonably fit in a barge?
- Can you score Algae + Coral with same mechanism?
- How far do we need to be from April Tag to line up with Reef?

Decision Matrix

On Day Two, groups split up to discuss their respective mechanisms to accomplish our must list. We used a Decision Matrix for each of our 6 groups: 2 discussing endgame, 2 discussing an intake, and 2 discussing the lift mechanism.

Idea	Weight	Complexity	Speed	Ease of use	Season Growth	Goal Alignment	Plays Well With Other Mechanisms	Value	%Vs Best
D2 - Horizontal Roller	7	4	10	8	8	9	9	194	100%
D3 - Vertical Roller	9	4	9	7	8	9	9	172	88.65979381%
D1 - All Scoop	3	3	8	2	2	9	5	94	48.45%
4Bar Retractable Intake	3	3	7	8	7	9	8	176	100%
Sidewinder Intake	7	4	7	8	6	7	4	106	60.23%
2018 Style Wrist Passive Intake/Scoring*	4	4	6	5	5	6	7	104	59.09%
Weighting [1-10] (Do	-4	-20	8	6	6	6	8	652	

Idea	Weight	Complexity	Speed	Ease of use	Season Growth	Goal Alignment	Plays Well With Other Mechanisms	Value	%Vs Best	Comments
chuck it from end of elevator*	3	4	8	6	6	5	8	156	47.85%	
Extending Elevator	7	5	9	8	7	9	6	136	41.72%	
tilted elevator	7	5	9	9	7	9	5	134	41.10%	
Telescoping Elevator	6	9	8	8	5	10	10	326	100.00%	may need 2?
Carriage Elevator	7	6	9	10	5	10	9	323	99.08%	potentially launch Alg
Scissor Lift	9	10	5	9	2	1	5	317	97.24%	L4 very iffy (stability)
Weighting [1-10] (Don't Edit These)	-4	-20	8	6	6	6	8	652		

Idea	Weight	Complexity	Speed	Ease of use	Season Growth	Goal Alignment	Plays Well With Other Mechanisms	Value	%Vs Best
Deep Climber Foldup	4	5	6	5	7	10	4	96	64.86%
Deep Climber Hug	6	7	5	9	7	10	4	64	43.24%
Deep Cage Climber Tricep Press	3	7	5	5	3	10	8	60	40.54%
Single Clamp+Rotate	3	4	7	6	5	9	8	148	100.00%
Internal Gripper+Rotate	3	5	8	7	5	9	8	142	95.95%
Surround Cage Climb	2	3	9	7	5	9	1	138	93.24%
Weighting [1-10] (Don't Edit These)	-4	-20	8	6	6	6	8	652	

OVERALL OUTCOME

- MANIPULATOR : Horizontal Roller Intake
- ENDGAME : Single Clamp and Rotate Style Climb
- ASCENDER : Elevator

INITIAL PROTOTYPES

PROTOTYPING DECISIONS

To begin designing our mechanisms, we used a Decision Matrix to narrow down some top ideas, most of which were based on previous years' designs. We decided on an elevator lift and a horizontal roller intake, but we still didn't know how to best manipulate the Coral. Student groups brainstormed ways to consistently and repeatedly pick up the Coral and a few questions arose: orientation of the Coral in intake, transition to the scorer, and orientation of Coral when scoring.

To explore these questions, we first built an "Alphabot"—a basic robot chassis designed for rapid prototyping rather than competition legality. The goal was to play the game as early as Week 1 and test game pieces maneuverability. By removing competition constraints early on, we could explore a wide range of ideas before refining them to fit within the rules. We made an extremely rough draft over-the-bumper intake, named the "Wall of Rollers", made of compliant wheels to see how it manipulates the Coral.

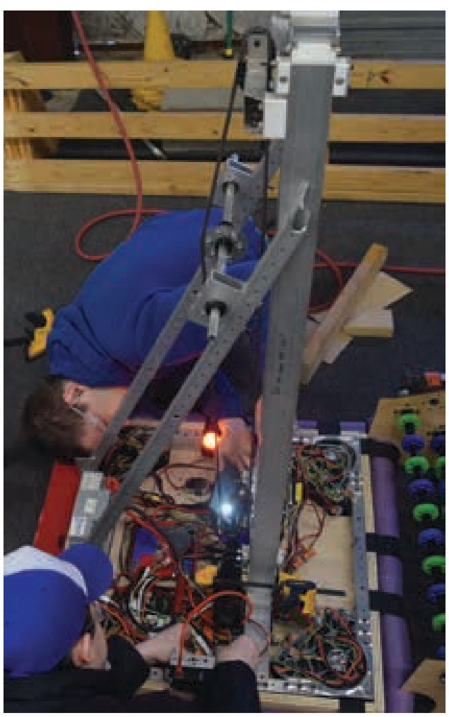
Picking up perpendicular Coral posed an initial challenge, but using a swerve drive base to maneuver around it resolved the issue. From prototyping various fixed angles, we found 45° to be the ideal scoring angle. Only one question remained: how to transition between the two? Our Alphabot helped provide a solution to this, as our "Wall of Rollers" simply dropped the Coral into the Coral scorer, but we still needed to sort the Coral to one side to help with this drop.

Students decided to test and prototype three main styles, each with their own purposes for the competition robot: two of these were actively indexing intakes using mecanum wheels and sushi rollers then PVC rollers with gripped tape, respectively and a third using a belt to translate the Coral to the side after intaking.

Square Elevator

The square elevator was the first prototype for our ascender mechanism. We wanted to better understand the height that was needed to successfully place the Coral on the Reef. This prototype was a carriage elevator made out of metal square tubes that were 48 in. tall which has a possible extension of around 72 in. We had made this as an offseason project in 2020, so we were able to get a quick elevator system for our Alphabot in a timely manner.

The Alphabot's Coral scorer was a plank of wood that was positioned at 45° because is was one of the best angles to score Coral on all four levels. It also allowed us to hold the Coral with some simple compression of around ¼-½ in. We added a planetary motor (25:1) to a belt. At the end of the scorer, we used three 2 in. wheels which allowed us to fix the placement of Coral until we hit the correct height. We also added walls to both sides of the Coral scorer so we don't lose the game piece when moving around the field.



PROS:

- Was quick to assemble
- Easy to program

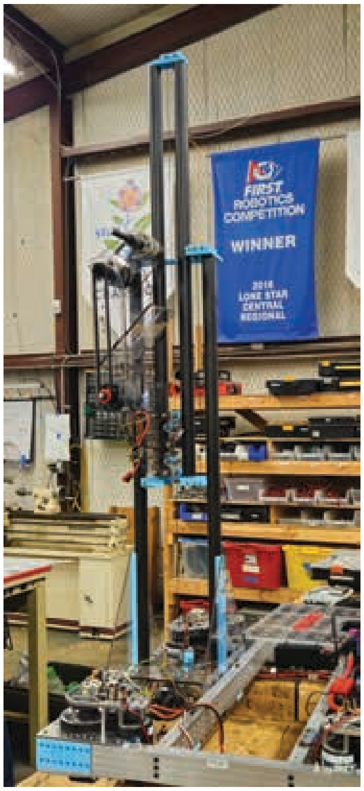
CONS:

- Over Height limit
- Coral wasn't secure
- Very slow to rise
- Used Chain

Circular Elevator

Our second carriage elevator design used carbon fiber tubes instead of aluminum tubing to stay lightweight. This iteration stands 41.75 in tall unextended and allows us to reach a maximum height of 72 in. all while measuring ~4.6 lbs. without the Coral scorer. This elevator has continuous rigging meaning that one stage has to completely finish before proceeding to the next stage. We also used Polycarb and 3D prints to build our elevator system. We used two Krakens with a 1:1 gear ratio with a cable capstan to hold all the cable necessary.

The CF elevator's Coral scorer was a improved design still using the 45° angle tested previously. It was mounted to the elevator's carriage and was able to move vertically with the first stage. It was assembled with a mix of ⅛ - ¼ in. thick Polycarb plates, ½ in. hex shafts, and 2 in. compressible wheels. We used a Kraken motor with a 2:1 gear ratio and added a time of flight sensor so we can detect if our robot has a game piece.



PROS:

- Lightweight
- Very Fast
- Unique design
- No need for Bearing Blocks

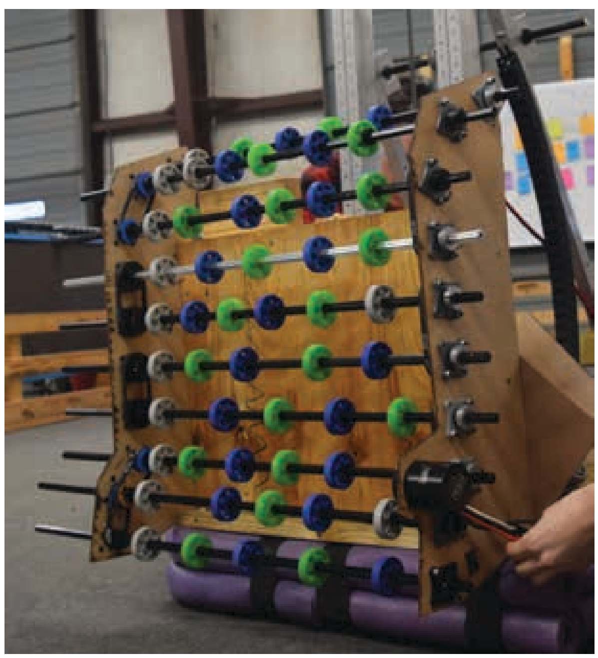
CONS:

- Not Rigid or Stable

Wall of Rollers

The "Wall of Rollers" was our first intake prototype. Our goal was to prove that we could intake Coral and drop it off directly into the Coral scorer. This aptly named prototype consists of around fifty small compliant wheels, twenty pulleys, at least forty shaft collars, and ten ½ in. hex shafts. As a result, this intake was 27 in. wide, 25 in. tall, and weighing ~12 lbs.

This colossal intake was able to intake from the floor efficiently, proving that a ground intake for Coral is a viable option, instead of having to directly funnel Coral from the Coral Station. This intake was powered by one NEO with a 5:1 planetary gearbox.



PROS:

- Extremely simple
- Easy to assemble
- Easy to troubleshoot

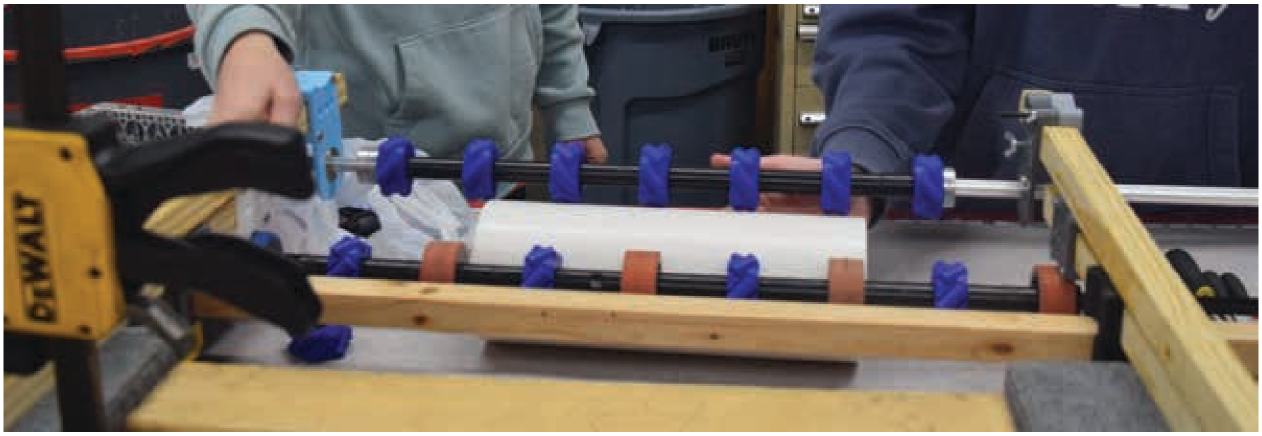
CONS:

- Used lots of materials
- Used ALL of our compliant wheels
- Easily broke

Mechanum Wheel Intake

Our second prototype was made to test the possibility of indexing while intaking. Mechanum wheels were the obvious choice for this, so a few hours later, we were ready to test using 3D printed wheels. The intention was to actively index the Coral while the rollers were spinning in opposite directions to intake.

This used two rollers that consisted of five 50A 1 in. sushi rollers and eleven 1 in. 3D printed mechanum wheels spaced 2 in. apart. While it was more consistent at intaking because of the sushi rollers, the mechanum wheels were too rigid and barely translated the Coral left/right due to a lack of grip. The rigidity also caused issues with the Coral jittering which shifted all the pieces of the prototype around.



PROS:
- Better grip for intaking
- Mechanum wheels were made in the shop

CONS:
- Bad grip for indexing
- Rigid horizontal movement

Tape Spiral on PVC Rollers

This prototype utilized multiple rollers to index, by latterly moving the Coral to one side. This mechanism would avoid having a separate transfer mechanic to get the Coral from the intake into the scorer. We thought that the difference in materials would cause the translation which it did, but never fast enough.

Using multiple PVC tubes and varying types of tape, we observed different speeds and grips on the Coral. We spiraled the tapes around the rollers in opposite directions to push the Coral to one side. Foam insulation tape worked the best because it had much more compliance than gaffers or Cat Tongue, but all of them wore down extremely quickly and peeled off after 2-3 uses. Due to the lack of compliance in the Coral, we could never hold it at the right strength to have it move.

PROS:

- Intake when the Coral was parallel to the rollers
- Cost efficient

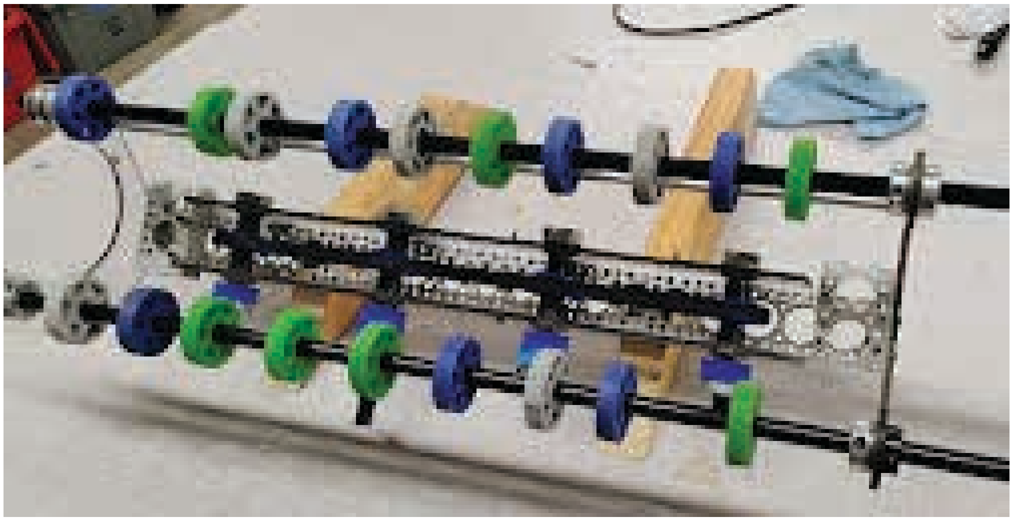
CONS:

- Didn't move fast enough
- Coral would slide away if not approached slowly
- Angle too shallow

Intake with Inside Belt

This was our fourth and final attempt at prototyping the intake. This prototype consists of two intake rollers with 2-inch compliant wheels and a belt system positioned behind them. This design achieved a full grip around the Coral, minimizing the risk of losing it during movement. The belt demonstrated a much stronger grip on the Coral, allowing for smooth and efficient transfer directly into the scorer.

The entire system was assembled using laser-cut Polycarb plates, which were mounted to two blocks of aluminum prototyping box tube. To achieve the decided angle, we used 2x4s to position the intake at 45°, which we found to be the most effective placement.



PROS:

- Consistent "touch it own it"
- Quickly indexed the Coral
- On hand materials
- Simple maintenance

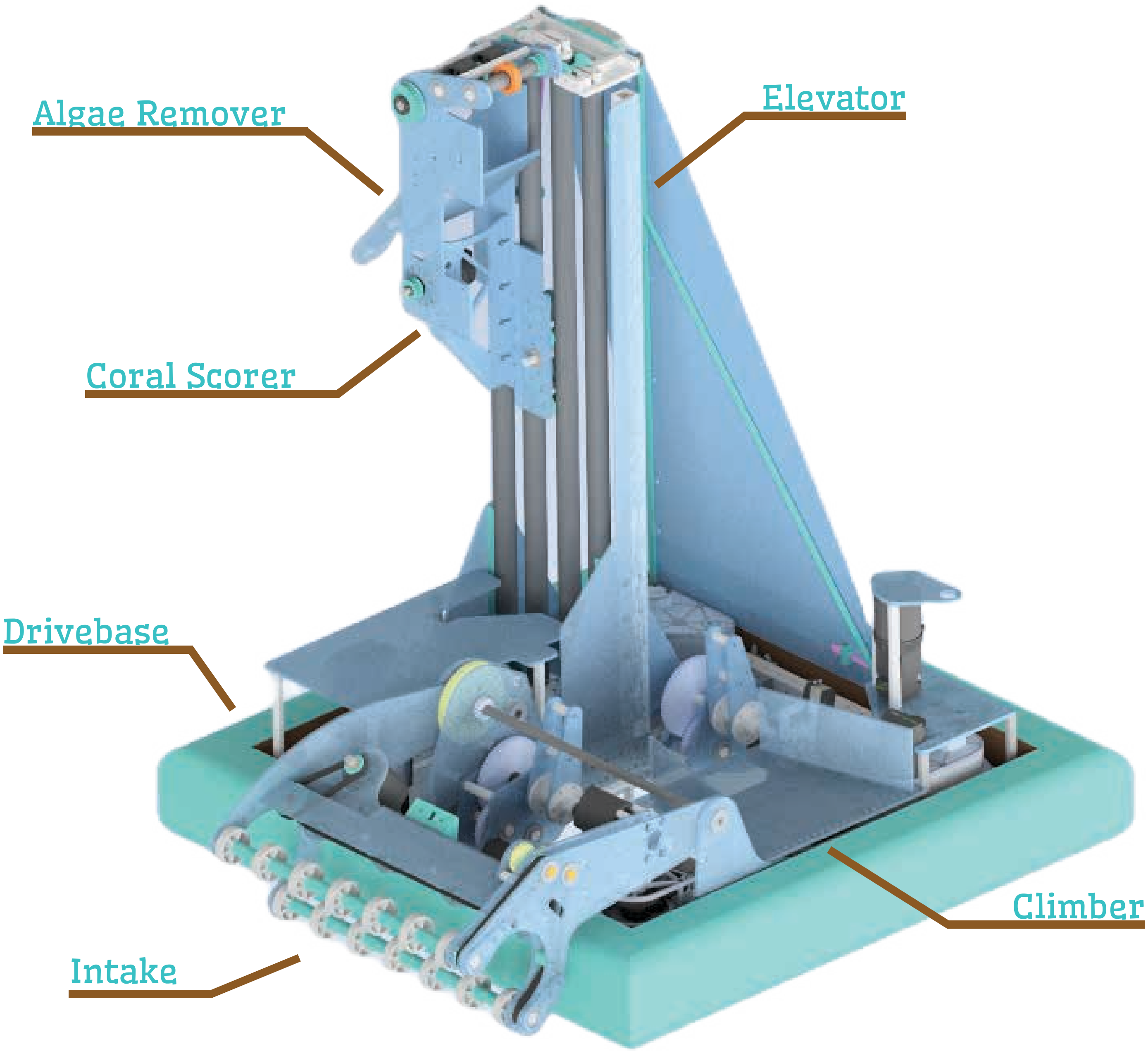
CONS:

- Compression needed to be changed

ROBOT DESIGN

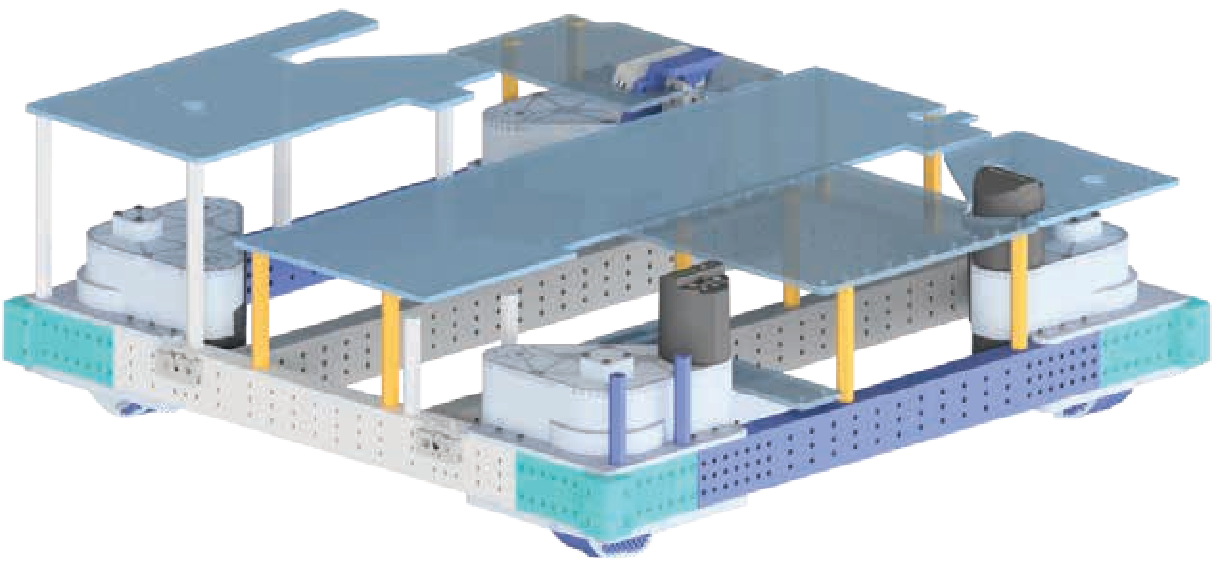
SIREN

Dimensions: 27" x 27" x 41.5"



Drivebase

The drive train is the base of the robot design and allows quick maneuvers around the field using swerve modules. There is a uniquely empty area at its center to house our climber. Due to this, there is a divide through the center of the robot, causing the main electrical components to be housed on the opposite side of the scoring mechanism. The design also includes a quick latch bumper system for sub 10-second bumper changes during competition, and the battery is housed under the intake on the same side as the electronics.



FUNCTION:

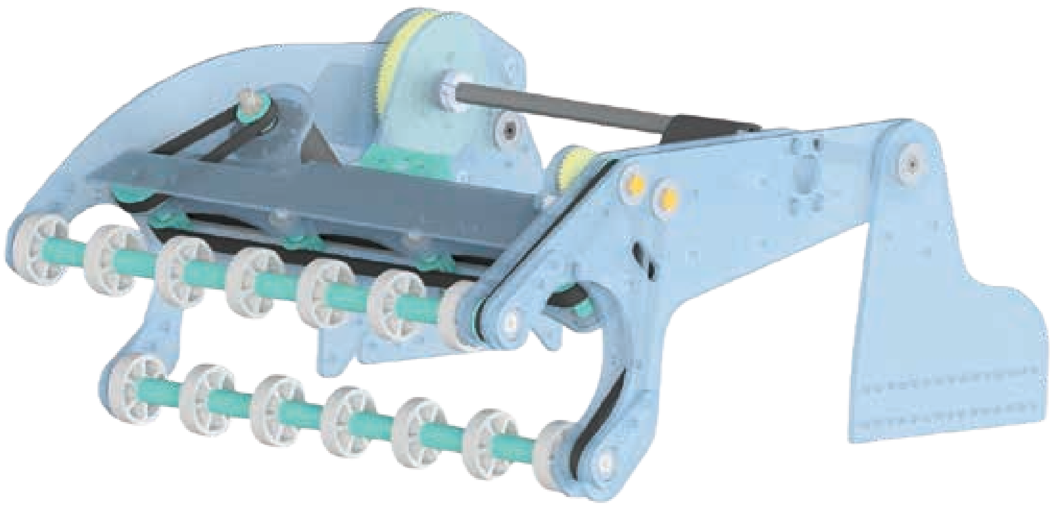
- 8 X60 Kraken Motors
- Custom Swerve Pod Covers
  - 3D printed PLA
- ~530 in^2 Polycarb cover for Electronics

CONSTRUCTION:

- 27" x 27" frame perimeter
  - 25" x 8" hole in center
- Crossbeams contains 150 holes
  - Easily configurable

Intake

The intake is a pivoting arm which has two horizontal shafts with compliant wheels to grab the Coral and contact it with conveyor belt transfer to the scorer on the elevator. It can intake off the ground or from the Source. The intake can also pick up Algae from the ground to score into the processor by simply outaking. When the Coral is being moved to the elevator or held for transportation, the intake is fully constrained within the bounds of the robot. The intake is almost fully made out of polycarbonate, to make it lightweight and flexible yet durable enough to not break upon contact by another robot.



FUNCTION:

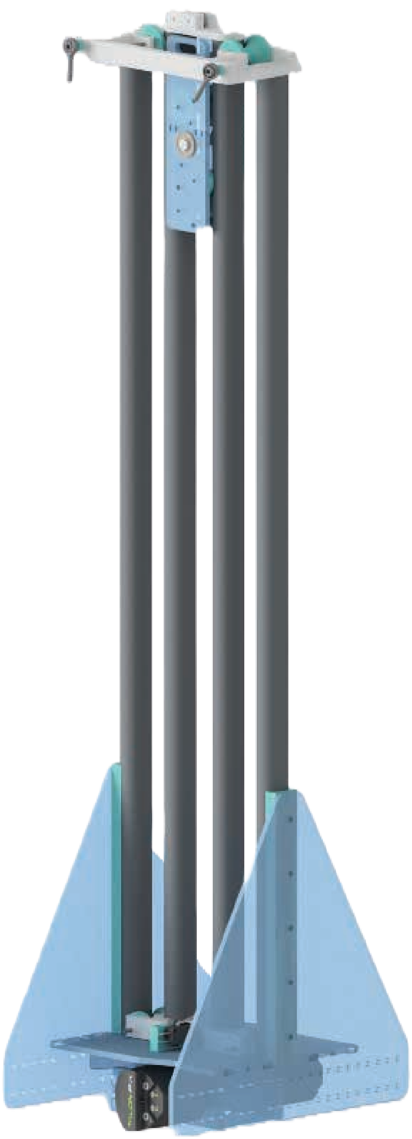
- 170t Belt for Conveyor
- 0.5 in. compression between two rollers
    - 0.25 in. compression from wheels to conveyer
- Pivot motor ratio 60:1

CONSTRUCTION:

- Rotational Motion: 0° to 138°
- Hardstop to transfer system
- 12 Grey 30A Durometer Compliant Wheels
    - 6 per roller

Elevator

The Elevator is the transport system that allows our robot to gain vertical height for scoring at different elevations that this game requires. Our lightweight design from using Carbon Fiber allows our moving mass to be ultra-light and allows us to extend vertically faster. We used a carriage elevator that allows us to pick up coral from our intake and have less moving parts on the elevator. We implemented a Polycarb E-Chain to manage the wires throughout travel as this allows for forces that more traditional e-chains cannot handle.



FUNCTION:

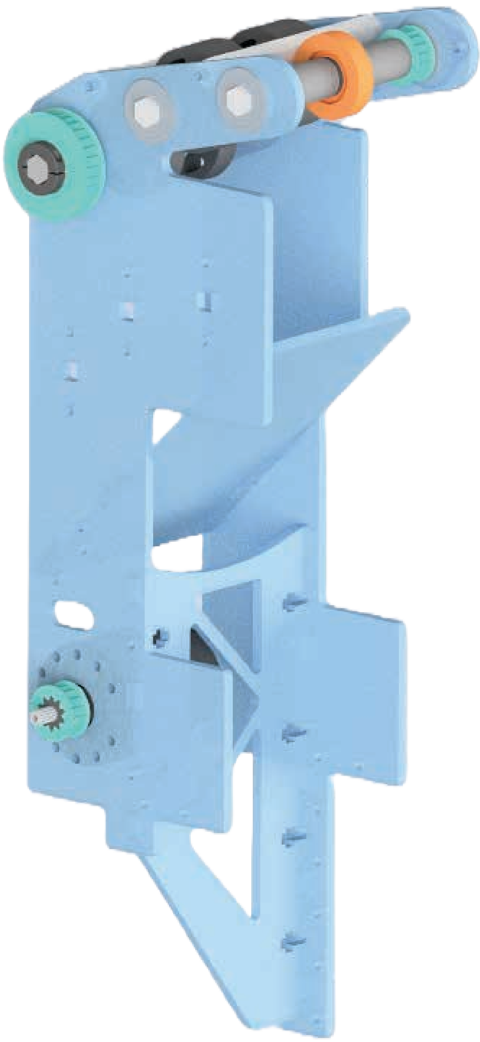
- 1:1 Gear Ratio With 2 Krakens
- 25" Dyneema Cable
  - Capstan Driver
- 3D Printed concave rollers
- Ratchet tensioning system

CONSTRUCTION:

- Travels 60" vertically
- Carriage Elevator
  - Continuous Rigging
- 36.25" long Carbon Fiber tubes
  - Lightweight at ~4.6 lbs
  - 28mm ID, 30mm OD

Coral Scorer

The Coral Scorer was designed so that the intake subsystem would feed directly through it at the lowest stage of the elevator. It is angled at 45° for convenient scoring on all levels without needing to pivot. The Scorer also includes compliant wheels at the transition point from the intake to have more control of the coral as well as making a quicker handoff between subsystems.



FUNCTION:

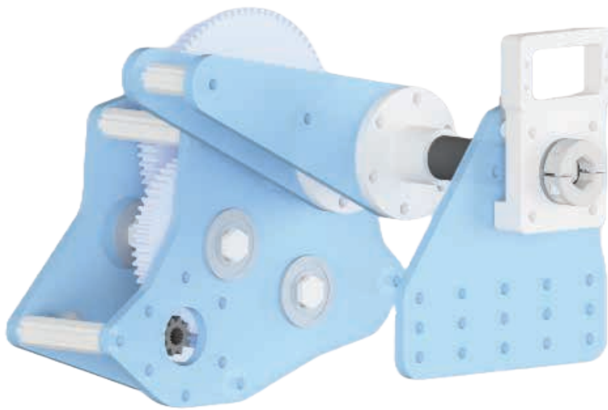
- 2:1 Gear Ratio powered by Falcon 500
- Scores at 45° fixed angle
- 3 rollers to redirect coral
  - 2" compliant and T40 BaneBots' wheels

CONSTRUCTION:

- Reaches above the carriage rigging
- Polycarb Biscut Joint assembly

Climber

The climber allows our robot to ascend onto the Deep Cage at the end of the game, and has the unique feature of being located in the center of our robot. This is to ensure that the Cage can be positioned as closely to the center of mass of the robot as possible, allowing a fast climb of minimal distance with little Cage swing. The climber is composed of two mirrored systems on the front and back of the robot, utilizing a CAM and a custom gearbox pointing in towards the center on each side. Each CAM is able to rotate down, lifting the robot by leveraging the base of the Deep Cage.



FUNCTION:

- CAM Mechanism
  - Carrot shape
- Custom gearbox with 126:1 reduction
  - Driven by 1 Kraken

CONSTRUCTION:

- 2 Identical Mechanisms
  - Mirrored around the center hole
- Servo Pawl Backdrive Prevention

Algae Remover

The Algae remover is an arm on a pivot mounted to our elevator, it reaches below high algae (L3), and above low algae (L2), in order to remove it from the reef so we can score. It works by positioning the arm above or under the algae, then driving the robot backwards to pull it out. It uses a push pull cable to transmit motion via a cam from another part of the robot. This gives us flexibility in mounting, and also allows us to route rotational movement throughout the robot.

FUNCTION:

- 80:1 Gear Ratio powered by NEO

CONSTRUCTION:

- 3' Push pull cable

SOFTWARE DESIGN

Software Engineering Practices

CODEBASE MANAGEMENT

To manage changes to our codebase efficiently, we primarily use GitHub. Each feature or fix is developed on a separate branch, allowing us to work on multiple changes simultaneously without interfering with the main branch. To keep track of who is doing what and what still needs to be done, we use a KANBAN board.

Whenever a feature or change is ready, we create a pull request to review and filter the additions before merging them. This process helps us track individual commits, compare file changes, and prevent new features from unintentionally breaking existing functionality. Each pull request requires both student and mentor reviews. We also encourage peer code reviews, fostering collaboration and deeper learning.

By maintaining this structured approach, we ensure that all the features being developed work efficiently and cohesively, maximizing the performance of our robot's mechanisms.

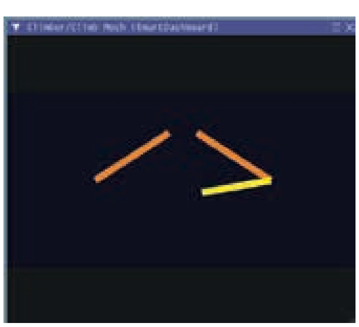
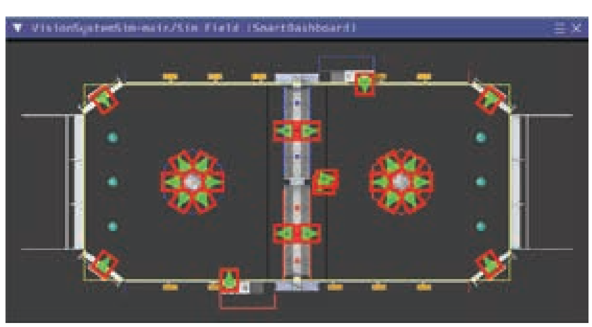
Simulation

Simulating our robot's mechanisms has been a game changer for our team. It allows us to test and fine-tune our code without needing extra robot time. The time we save means we can focus on improving autonomous routines, optimizing code, and refining strategies, rather than spending valuable field time debugging issues.

The simulation works by taking real measurements from our CAD model and inputting them into a simulated mechanism. WPILib provides base models for common mechanisms like an arm, elevator, or flywheel. These models are flexible enough that, with the right combination, we can simulate almost any mechanism you can think of.

Once we determine the correct models for a given mechanism, it's just a matter of plugging in the right values, and creating simulated instances of our motors. This process usually takes only a meeting or two, but it allows us to start testing and debugging before we even have a physical robot on the field.

Beyond just debugging, simulation has changed how we approach robot development. It gives us the ability to experiment, refine, and validate ideas faster than ever before. Whether it's testing a new autonomous routine, tuning a mechanism, or predicting hardware failures before they happen. Simulation has become an essential tool for our team as we continue to push the limits of our robot's capabilities.

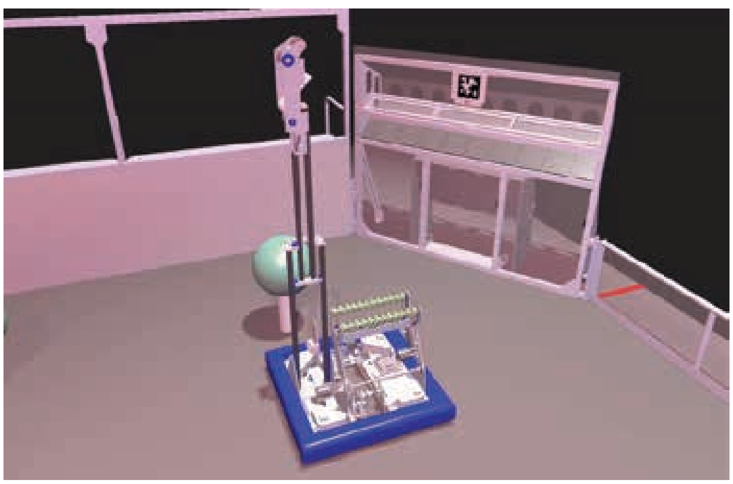

PAST EXPERIENCES

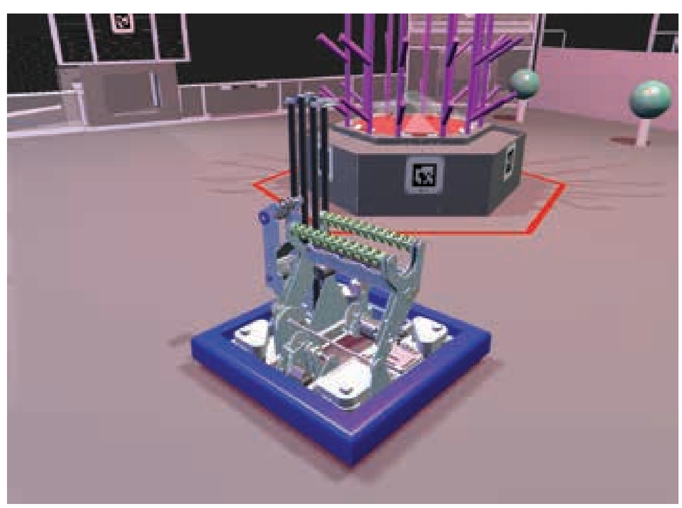
Simulation has even helped us avoid mechanical failures. Last season, while testing our Amp mechanism, the simulation indicated that the motor was struggling to move the mechanism. At first, we assumed this was due to incorrect CAD values or a programming issue. However, when we tested it on the real robot, the motor overheated and failed—exactly as the simulation had predicted. After upgrading to a more powerful motor, we saw significant improvements, and the simulation confirmed that the new motor would work as expected. This experience taught us to trust our simulation results and investigate potential issues before they become real-world failures.

Physics Sim

For this season, one of our goals was to get more drive practice before our first competition. Instead of relying solely on extra robot time, we built a full physics-based simulation of our robot. Our simulation models the entire robot, including the elevator, intake, odometry, and even vision using LimeLight.

This simulation is especially valuable for our drivers because it runs the exact same code as the real robot and stays up to date with the latest changes. We also integrated our actual CAD model into the simulation, allowing drivers to visualize the robot and get familiar with its layout—such as knowing which side is used for intaking versus scoring.



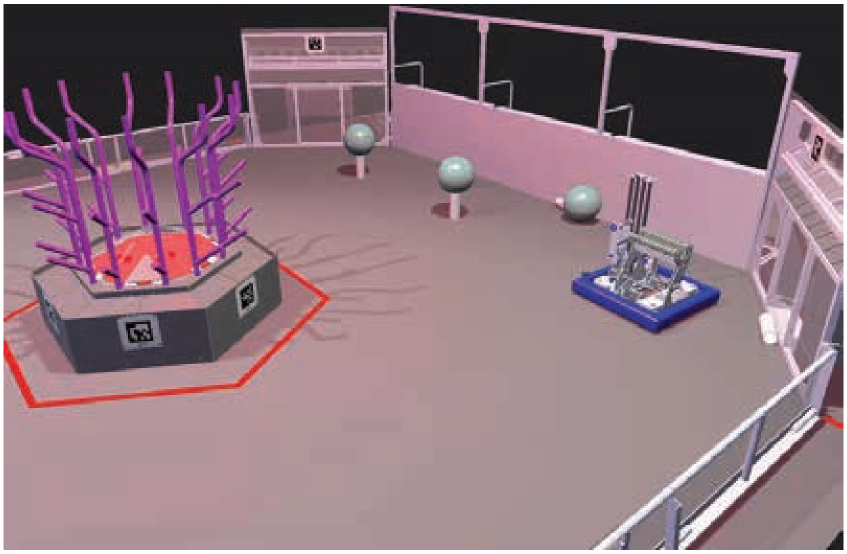


ADVANTAGE SCOPE

To visualize the simulation, we use AdvantageScope, a robot diagnostics, log review, and data visualization tool for FIRST Robotics. Its biggest "advantage" is the ability to break down CAD models into individual components and animate them in 3D space using real-time data or logs. By logging the pose (position and orientation) of each piece, we create a highly accurate and dynamic representation of the robot's movement.

While this aspect of AdvantageScope has been available for a while, this is the first time our team has fully explored its potential. Although we primarily use it for simulation, it's also a valuable tool for diagnosing issues on the real robot. By comparing log data to actual robot behavior, we can quickly identify discrepancies—seeing what the robot thinks it's doing versus what actually happens. This helps us pinpoint issues faster, reducing time spent digging through raw data.

Thanks to this tool, our main driver has gained several extra hours of practice before even touching the real robot. Once we had more accurate values from testing, we could also simulate autonomous routines, allowing us to verify logic before using real robot time. While simulation can't fully replace physical testing, it helps us debug, refine code, and optimize performance far more efficiently.



Intake State Machine

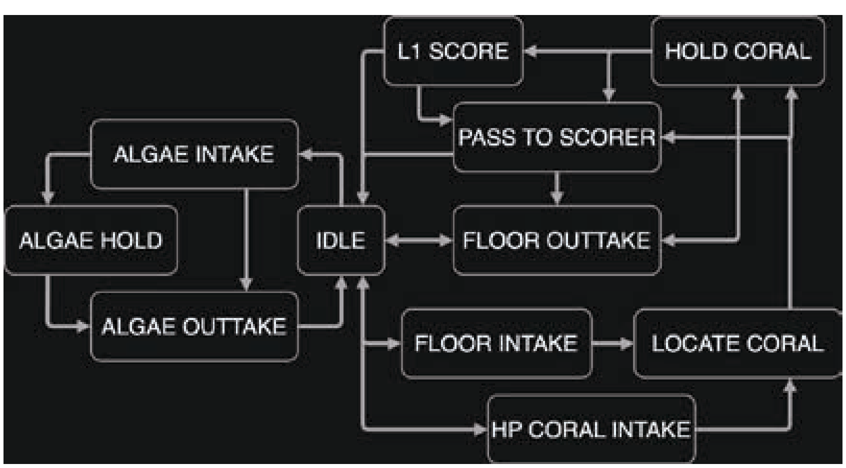
This season, our intake has proven to be a highly versatile tool. Initially, we designed it to pick up coral from the ground and feed it to our elevator. However, throughout the build season, we discovered that it could do much more—it can also pick up algae, score coral in Level 1 (L1), and intake from the coral stations. While this added functionality is a huge advantage, it also made programming the intake significantly more complex, as each action requires different components of the intake to behave in specific ways.

To help us manage this complexity, we developed a state machine that defines every possible "state" our intake can be in and outlines the valid transitions between them.

For example, when the intake is in the "Hold Coral" state, it has several options: it can A: Score the coral in L1, B: Pass the coral to the elevator/scorer, C: Outtake the coral onto the floor.

However, it cannot transition directly to the Idle state because the Idle state requires that no coral is present.

By structuring our intake logic with this state machine, we ensure that every action follows a clear set of rules, making our intake more predictable, efficient, and easier to debug.



LOCATE CORAL

When designing our intake, we identified a potential issue: if a coral entered off-center, part of it could extend beyond the intake's sides. If the intake retracted while a coral was hanging out on the wrong side, it could collide with the elevator and cause damage. To prevent this, we implemented the Locate Coral State—a system that ensures the coral is properly positioned before retracting.

This system is a state machine within our larger intake state machine. It uses three distance sensors on the intake to detect the coral's position. Based on this data, the system determines which direction to run the intake belt to center the coral and whether it is safe to retract the intake completely.

Some positioning cases are theoretically impossible if only one coral is inside the intake, so they are ignored in the logic. Our goal is to automate as much of this process as possible to reduce the driver's mental load. By integrating this state machine, we ensure a safer, more reliable intake system, allowing the driver to focus on overall match strategy rather than micromanaging intake positioning.

Sensor	2	3	4	Belt Direction	Can Arm Retract
Triggered	☑	☐	☐	Out	☐
	☑	☑	☐	-	☑
	☐	☑	☐	IN	☑
	☐	☑	☑	IN	☑
	☐	☐	☑	IN	☑
	☐	☐	☐	-	☑
Impossible	☑	☑	☑	-	☑
	☑	☐	☑	-	☑