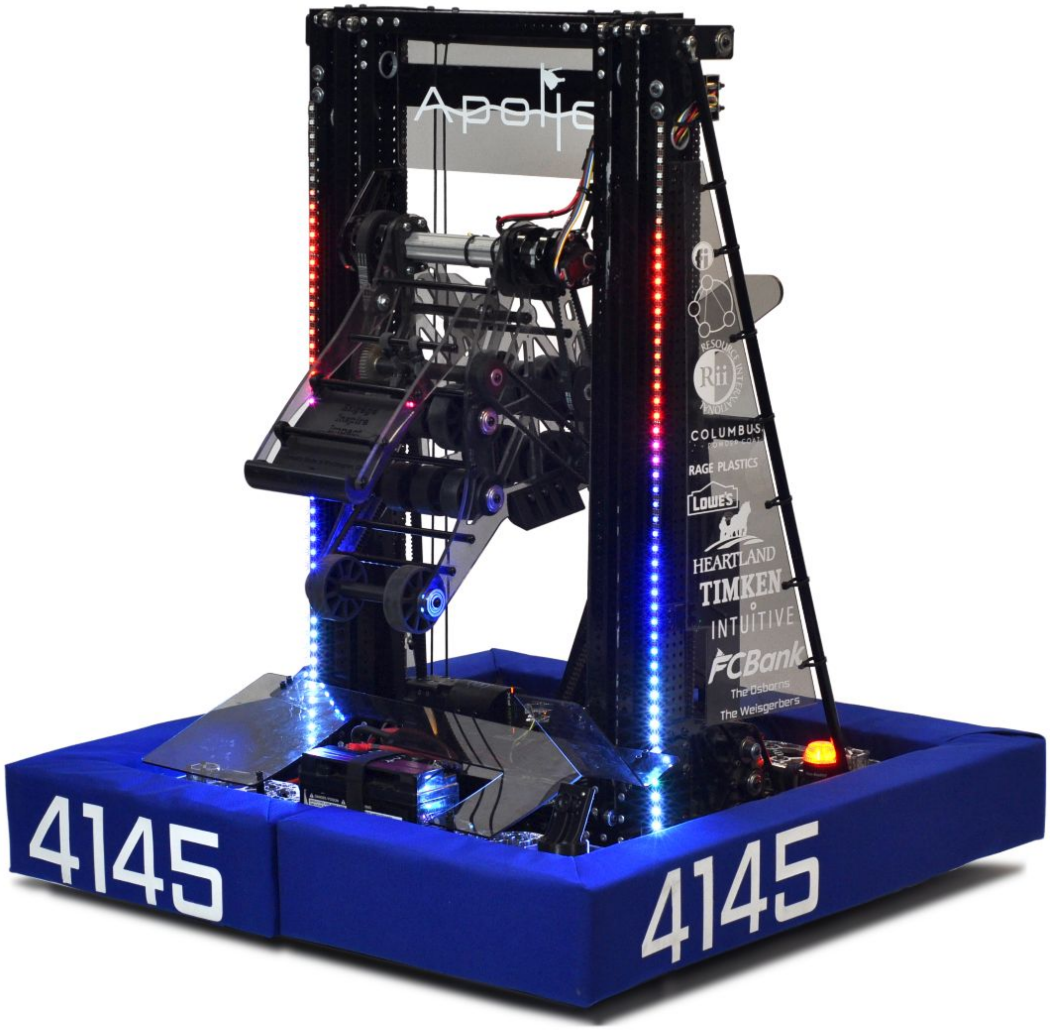
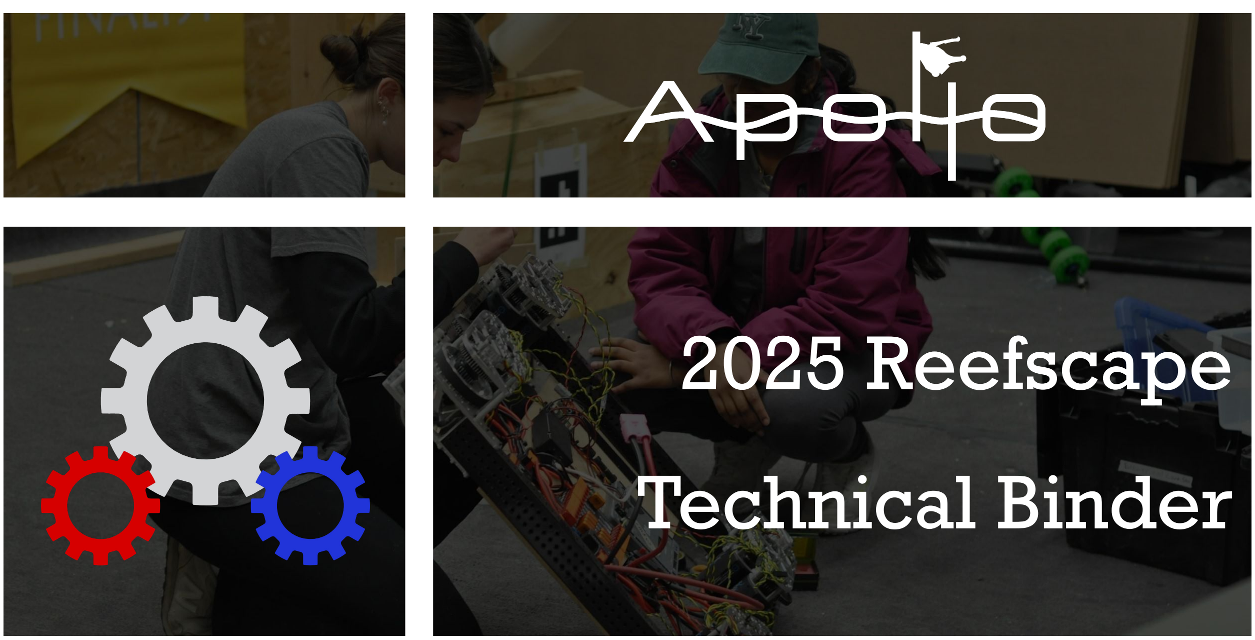




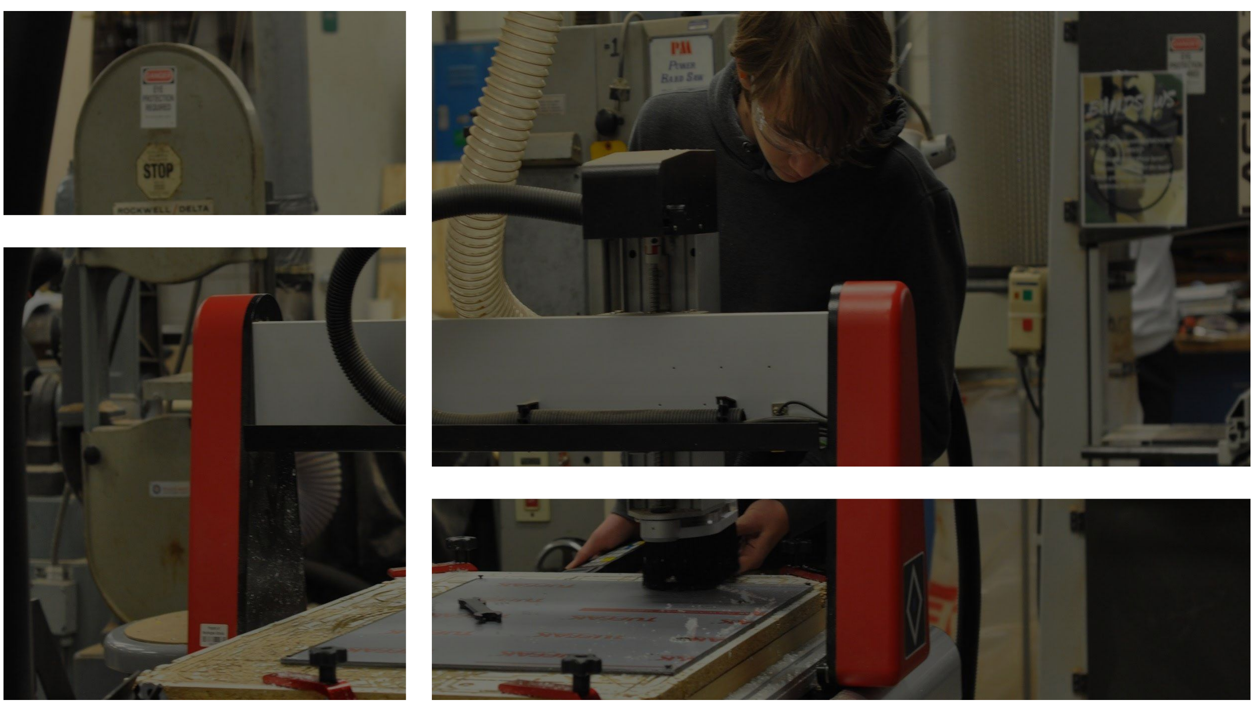
2025 Reefscape Technical Binder

FOREWORD

This Technical Binder outlines the game analysis, decision-making processes, resultant outcomes, and technical designs that informed the development of our final robot for the 2025 FRC Season: Reefscape.

At the beginning of each season, every member of the WorBots gathers together for our kickoff, followed by team brainstorming sessions, including the ideas of all and serving as the basis for our design. From there, we establish lists of requirements and work to integrate team members' ideas into prototypes which are designed, fabricated, and improved upon for practicality. This is the starting point for our next phase, where we test and drive the robot—making necessary adjustments and *gearing up* for competitions. This technical binder covers the subsystems, design process, and programming that together form our robot for the 2025 *FIRST* Robotics Competition season.

The WorBots are proud to present our 2025 Robot: **Apollo**



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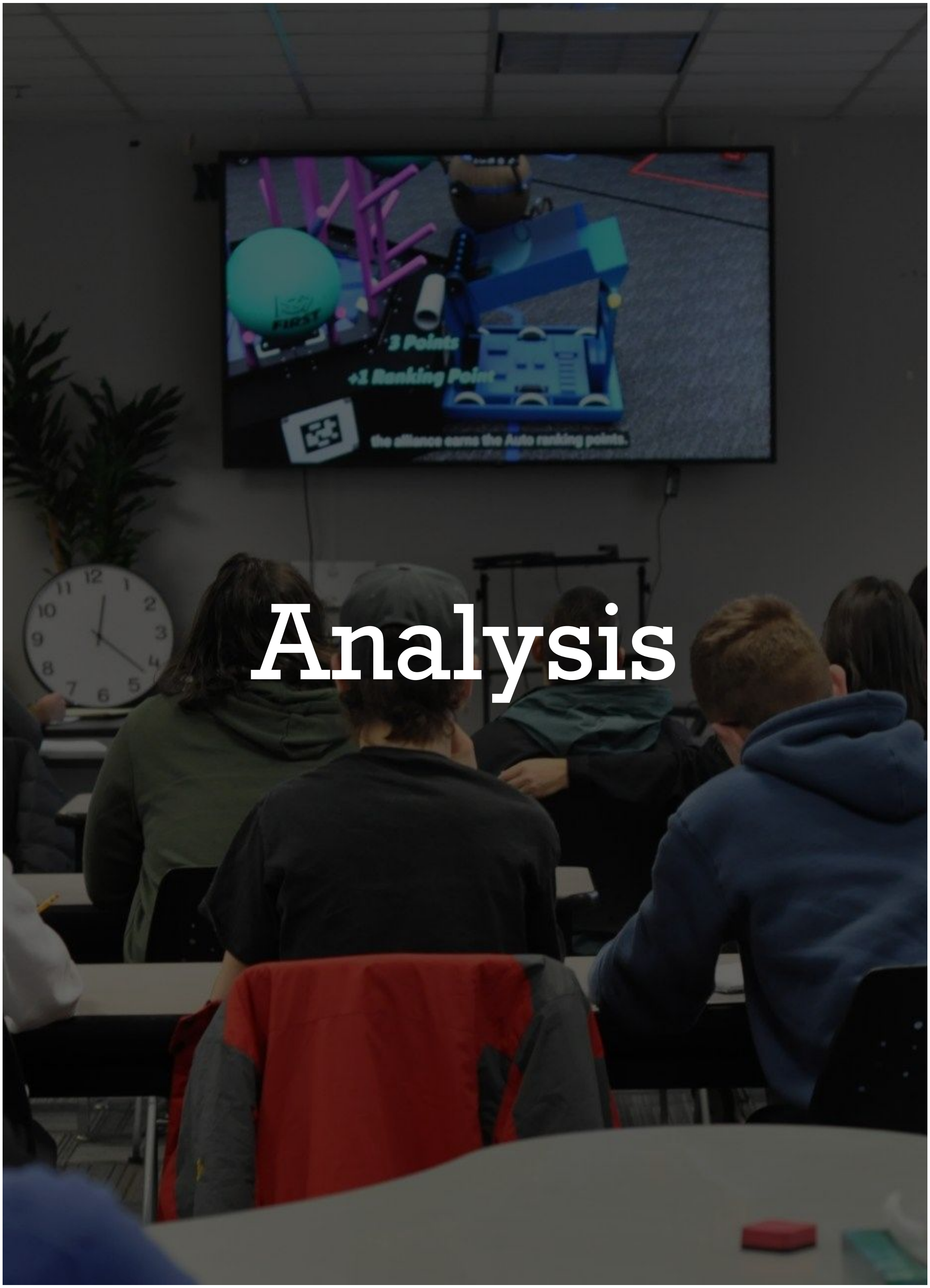
Analysis


3 Points
+1 Ranking Point
the alliance earns the Auto ranking points.

GAME ANALYSIS

REEFSCAPE is a complex game with multiple interconnected systems, requiring a well-rounded strategy to maximize scoring potential. Success depends on efficiently cycling coral onto the reef while also clearing space to enable effective barge and processor scoring. Achieving this balance is crucial, and our strategy is designed to reflect the following key principles:

Qualifications

In qualification matches, our primary objective is to secure and maximize ranking points rather than solely focusing on outscoring opponents. Since ranking points determine our placement for playoffs, we must balance all available ranking point opportunities to ensure consistency across matches. This means prioritizing tasks such as scoring in the algae processor to attain the coopertition bonus, ensuring sufficient coral placement to meet ranking point thresholds, and effectively utilizing autonomous scoring and endgame climbs. By maintaining a well-rounded approach that prioritizes these objectives, we increase our chances of consistently earning at least 4 ranking points per match, setting us up for a strong playoff position.

Qualification Match Strategy

Ranking points are awarded as follows: 3 points for winning a qualification match, 1 point for scoring 5 coral on 4 levels (or 5 on 3 levels with the coopertition bonus), 1 point if all robots leave the starting line and at least one coral is scored during autonomous mode, 1 point for scoring at least 14 points on the barge, and 1 point for a tie. To maximize our ranking points and overall performance, our strategy should focus on the following:

- Score 2 algae in the processor to attain the coopertition bonus
- Score at least 12 coral each match to ensure that we rely less on other teams
- If other teams are able to consistently score notes in the lower levels, we can score the higher levels to get the ranking point
- Climbing is a high priority, as a successful deep climb is an almost guaranteed ranking point, so leaving 20 seconds at the end of a match for climbing is crucial

By consistently achieving these objectives, our robot increases the likelihood of winning matches and securing at least one additional ranking point, making it highly probable to earn at least 4 ranking points per match.

GAME ANALYSIS Cont.

Playoffs

In the playoffs, ranking points are no longer a factor—winning is the only priority. As such, our strategy shifts from balance to outscoring the opposing alliance as efficiently as possible. While placing algae in the processor earns 6 points, it also allows the opposing alliance to score 4 points off of our contribution, resulting in only a 2-point net gain. Instead, we will prioritize placing algae in the barge, where we earn 4 points without giving the opposing alliance an opportunity to score off our actions. By focusing on maximizing our own scoring potential while minimizing the opponent's, we create the largest possible point differential, giving us the best chance to secure playoff victories.

Playoff Match Strategy

In playoff matches, we will be up against the best teams, and so we will have to change our strategy in order to get as many points as possible. That means:

- Focus on maximizing raw points rather than meeting ranking point requirements
- Prioritize placing algae in the barge (4 points each) instead of the processor (6 points), since processor-scored algae allow the opposing alliance to gain 4 points off our contribution (only a 2-point differential)
- Continue efficient coral cycling to maintain control over the reef and optimize scoring potential
- Maximize team communication to fill the reef efficiently and effectively
- Adapt based on alliance strengths—if our partners excel in certain areas, we shift our focus to complementary roles
- Ensure a strong endgame presence, leaving time for climbing to secure additional points

By focusing on maximizing our own scoring potential while minimizing the opponent's, we create the largest possible point differential, giving us the best chance to secure playoff victories.

SUBSYSTEM STRATEGY

Our subsystem strategy prioritizes reliability above all else. Speed is only valuable if performance is consistent and repeatable, so every system is built for robustness and efficiency. With a dependable drivetrain, end effector, elevator, and climber, we can execute our match strategy with confidence. Each subsystem is optimized to maximize overall performance:

Drivetrain

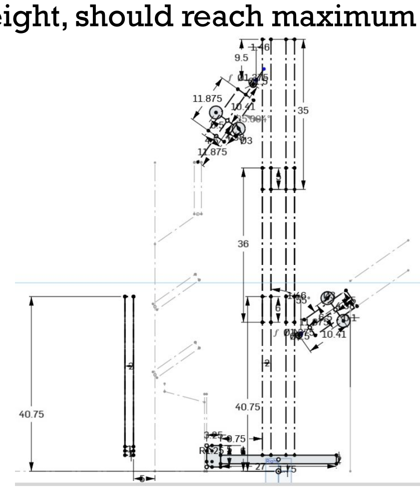
- Swerve drive system provides omnidirectional movement, allowing for faster cycle times and superior maneuverability to evade defensive robots
- Optimized chassis design should maintain a wide enough footprint and low center of gravity to minimize tipping, while remaining compact, lightweight, and agile for fast maneuvering and acceleration
- Robust and efficient control algorithms to optimize pathing and ensure smooth transitions between scoring locations

Game Piece Scoring

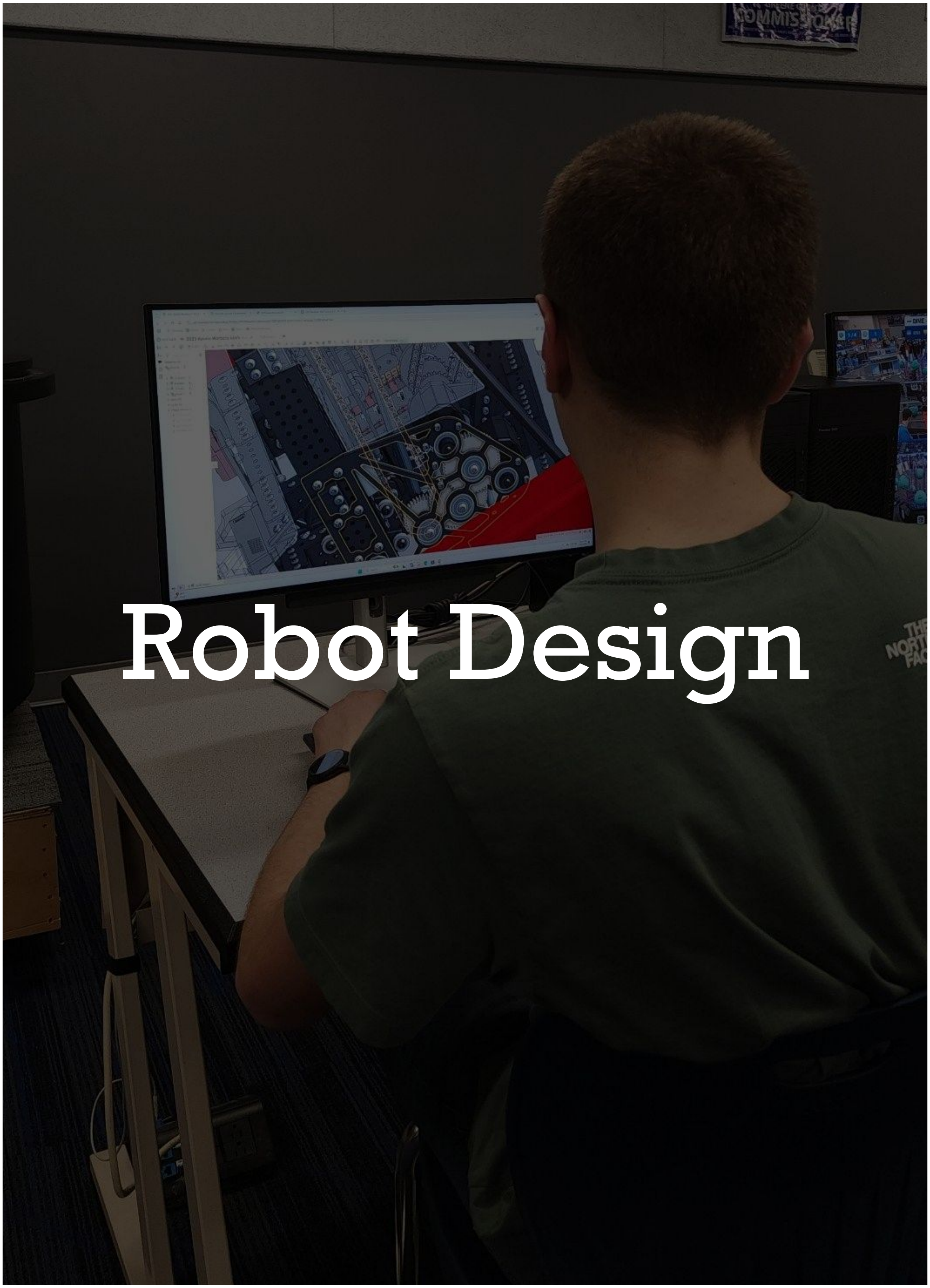
- "Touch it, own it, secure it"—fast and reliable intaking is essential for maximizing cycle efficiency
- Versatile placement system enables precise and consistent coral scoring at all heights
- Algae intake and scoring capabilities support rapid collection and seamless deposit at any level
- Durable polycarbonate frame ensures high impact resistance while maintaining a lightweight design to minimize torque on pivot
- Optimized roller and wheel mechanism to enhance grip and control, securing coral efficiently while minimizing misalignment
- Fast and reliable elevator to allow for variable height, should reach maximum extension in less than 2 seconds

Climbing

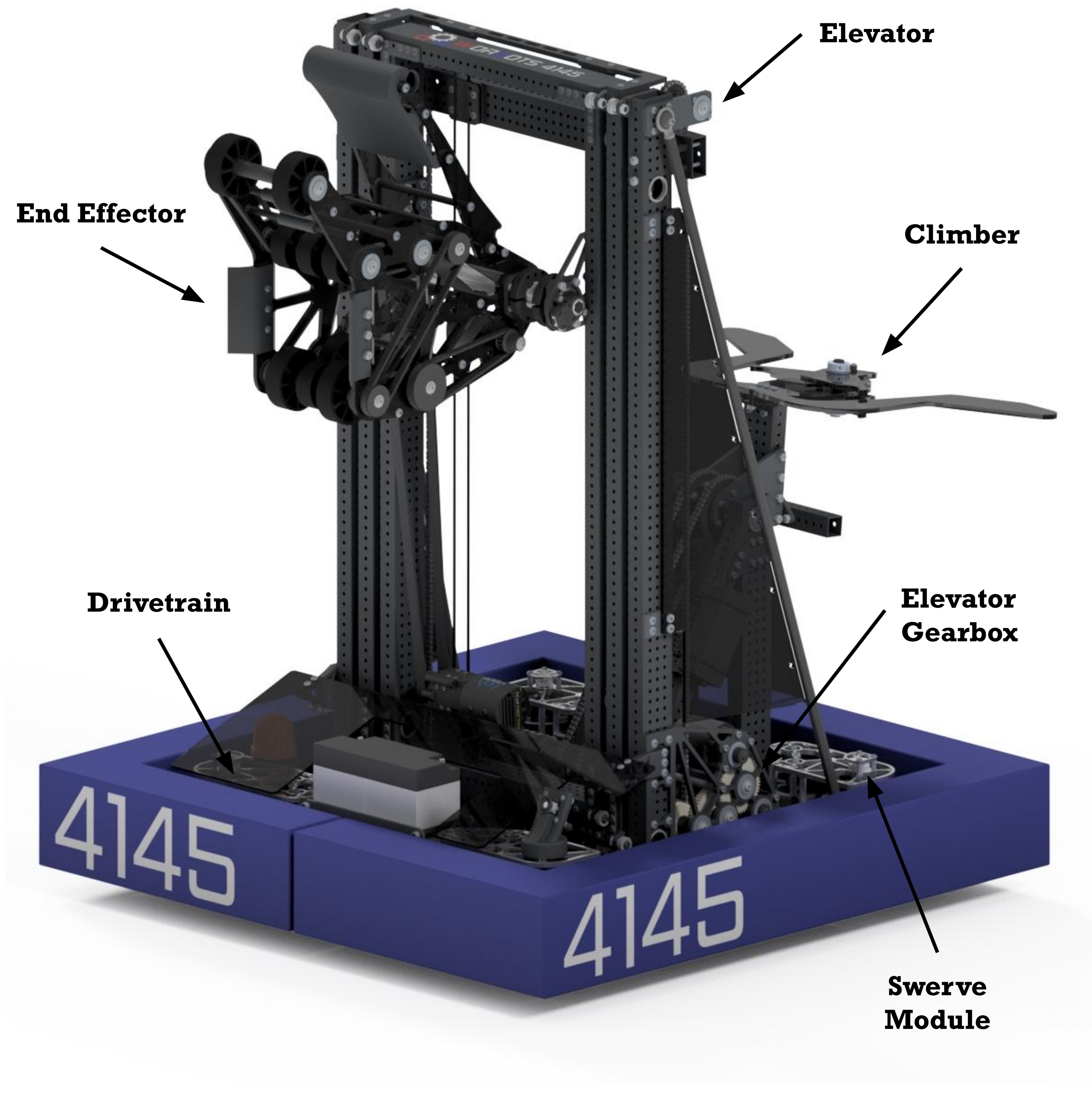
- Alignment assembly to guide the deep cage into place, so the hook system locks in place
- High-torque gearing system to enable strong and efficient climbs, preventing backdrive while keeping climb times low



Robot Design



Apollo



Elevator
End Effector
Climber
Drivetrain
Elevator Gearbox
Swerve Module
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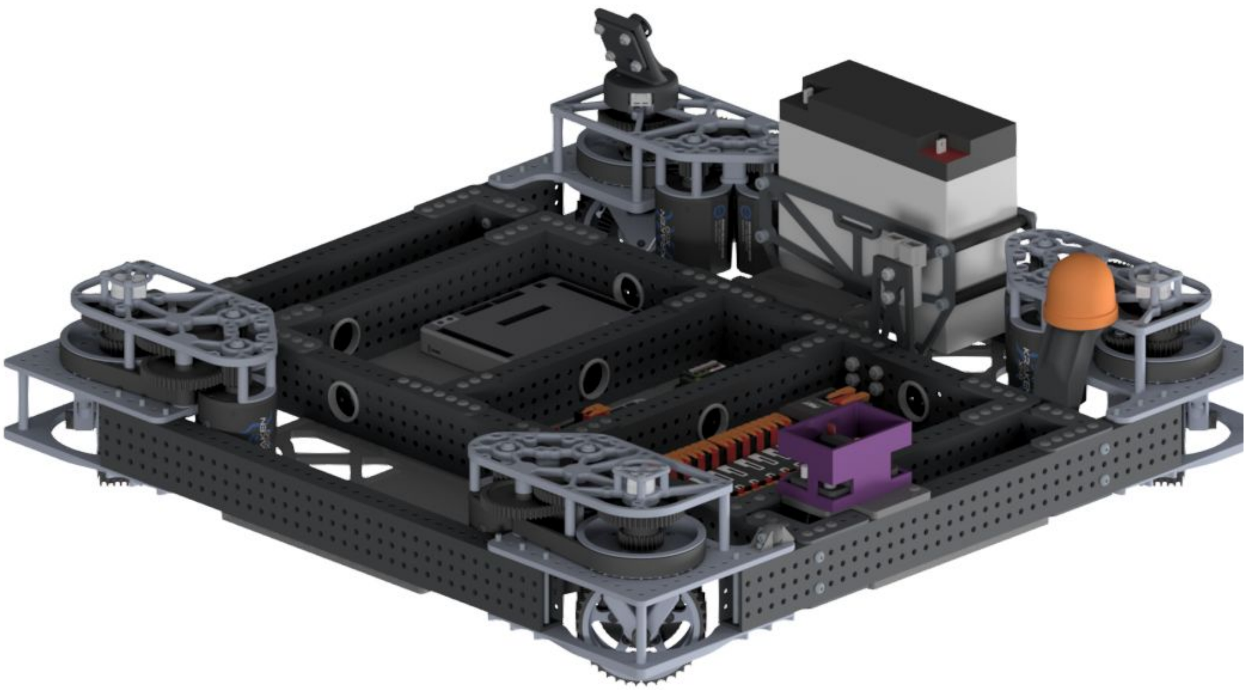
DRIVETRAIN



Our drivetrain achieves a favorable balance between power, speed, and agility, so that it can support every subsystem while being rapid enough to maneuver around defense and maximize cycle time.

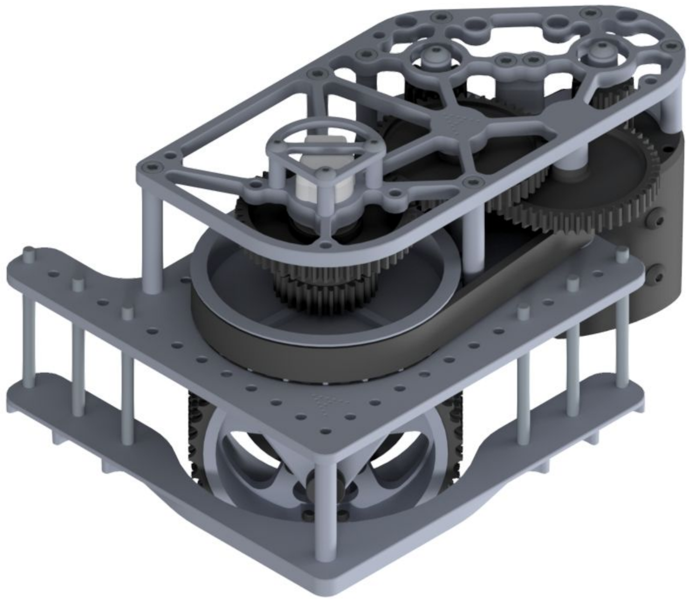
Chassis

- 2 in. x 1 in. x .125 in. aluminum tubing makes a lightweight yet durable structure
- Drivebase is 27 in. x 27 in. to minimize robot footprint, yet provide a stable base for vertical extension
- Swerve modules mount directly to the chassis in the standard configuration to prevent game elements from getting stuck under the robot

Base Plate

- 27 in. x 27 in. x 0.25 in. polycarbonate plate mounts to the bottom of chassis
- Electronics mounted around base plate for easy access and secure mounting
- Cutouts give swerve modules clearance to rotate

SWERVE MODULE



The swerve module provides optimal maneuverability and torque in an all-in-one package. Powered by 2 Kraken motors that control both the angular direction and rotational velocity of the billet wheel. This holonomic drivetrain option ensures a massive advantage for fast and efficient scoring.

Gear Train

- Wheel direction (Yaw) is controlled by a hybrid gear and pulley system
- Rotational velocity is through a 5.36:1 L3+ gear reduction

2 Kraken X60 Brushless Motors

- Kraken X60 motors provide more torque than a NEO or a Falcon 500 while providing comparable RPM
- Kraken motors come with an integrated high resolution encoder to provide accurate odometry for autonomous and tele-op movement
- CANCoders ensure an accurate startup position, eliminating the need for pre-match calibration

High Grip Wheels

- 4 in. diameter aluminum billet wheels for maximum ground contact
- Black nitrile high-grip treads for a balance of good traction and high durability

END EFFECTOR

The end effector system is built to quickly and consistently intake and score both coral and algae. Several sets of rollers quickly intake and align the coral so that scoring is fast and consistent. Both the coral and algae systems are driven by a single Kraken X60 motor.

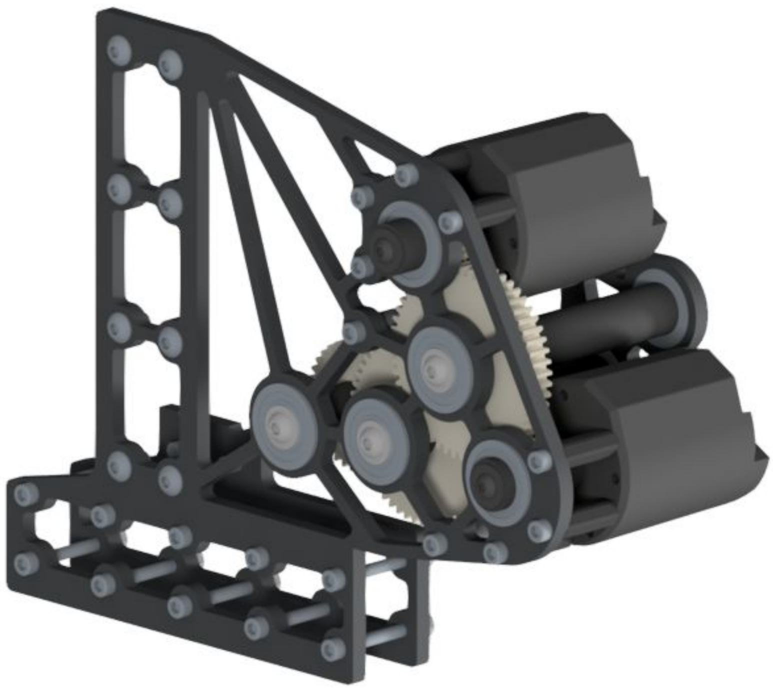
Coral System

- Two custom machined polycarbonate plates form a rigid frame for the end effector
- 3 in. and 2¼ in. high strength compliant wheels grip coral securely, ensuring successful intake of coral

Algae System

- 3-inch compliant wheels effectively agitate and dislodge algae from the reef, ensuring efficient collection
- A 3D-printed plate mounted on polycarbonate arms securely holds the algae in place during transport
- Elastic surgical tubing integration keeps the system low-profile while allowing it to passively extend when needed for algae intake

ELEVATOR GEARBOX



This custom gearbox system utilizes two Kraken X60 motors driving a set of gears to smoothly extend the elevator as it translates, resulting in accurate posing and reliable speed.

Gearbox System

- 9:1 gear reduction generates 126 Nm of torque, providing ample power to smoothly drive the elevator
- Rapid extension capability allows the elevator to reach maximum height in under 1.5 seconds, minimizing cycle time and maximizing efficiency

Structure

- ¼-inch 6061 aluminum plating, reinforced with ⅜-inch aluminum standoffs, ensures a strong yet lightweight frame
- Open design minimizes weight while allowing for easy maintenance and quick repairs during competition
- ½-inch aluminum ThunderHex axle connects the elevator driving sprockets to the gearbox, delivering smooth and efficient motion for precise amp scoring

ELEVATOR

The elevator employs a cascade lift system, ensuring maximum extension speed as all stages move in unison. Constructed from 2" x 1" x 0.0625" aluminum box tubing, the frame remains lightweight yet durable, while the two-stage cascade design enables consistent and reliable access to higher field elements.

Stage

- Driven by the elevator gearbox using #25-H chain, securely routed along the rear of the frame with chain combs for smooth operation
- High-speed cascading motion enables precise and efficient positioning for all game elements

Frame

- ¼-inch aluminum plates securely mount the elevator to the chassis, ensuring stability even at full extension while reinforcing the structure to counter tipping forces and maintain balance during operation

End Effector Pivot

- MAXSpline shaft provides a rigid, lightweight pivot axis for smooth operation
- Powered by a Kraken X60 motor with a 50:1 reduction, paired with a REV Throughbore Encoder for precise game piece manipulation

CLIMBER

The climber is designed for a secure deep cage grip, allowing the robot to lift its full weight and hold position with minimal backdrive. Constructed from 2" x 1" x 0.125" aluminum box tubing, reinforced with 1" x 1" x 0.0625" truss supports, it maintains high rigidity and strength, ensuring a stable and reliable climb every match.

Driving System

- Kraken X60 motor with a REV gearbox powers the climber barb through a chain and sprocket system, utilizing a 909:1 reduction to provide ample torque for a reliable and successful robot lift
- #25-H chain with WCP chain tensioners ensures a stable climb, minimizing the risk of chain malfunctions

Barb

- Layered polycarbonate plates compress upon contact with the cage, then lock securely in place once engaged
- Mounted to sprockets using 2" x 1" x 0.125" aluminum box tubing, reinforced with custom-machined 0.25" aluminum plates for durability
- A 1" x 1" x 0.125" aluminum box tube functions as a reaction bar, maintaining proper alignment during the climb
- A polycarbonate wing stabilizes swinging cages, improving consistency and ease of securing points in endgame scoring

Software

SYSTEM ARCHITECTURE

Subsystems

Subsystems are the individual, independent systems that run on the robot. There is only a single instance of each subsystem that holds access to actual hardware, following an industry-standard pattern known as the singleton. Its primary job is to read input data from sensors, perform calculations, and then output to actuators that perform tasks on the robot. However, they do not contain any complex logic and have no access to other subsystems.

For each periodic loop cycle, each subsystem will run this process:

1. Update sensor inputs from the IO objects inside of them. These IO objects allow us to abstract away the actual hardware, and easily adjust for new hardware changes or simulation.
2. Output to actuators like motors with whatever control setpoint we desire, using the inputs to inform more complex control loops.

These subsystems create an API for our autonomous routines and drivers to call into to allow for a further degree of abstraction.

Commands

Like many teams in FRC, we use commands to orchestrate all of the subsystems on our robot together for driver control and autonomous routines. While subsystems can't talk to each other on their own, commands can control as many subsystems at once as is needed to complete tasks on the robot.

PIDs

PIDs, or proportional, integral, and derivative controllers, are used in a number of places on *Apollo*. These controllers allow the subsystems to make smooth motions and correct for errors that can occur over the course of operation. Almost every subsystem leverages PIDs. The drivetrain uses them to control the speed and rotation of each individual swerve module. The elevator and pivot are also controlled by PID loops. In addition, PIDs can be used inside of commands, such as an angle PID for turning the robot in a specific direction while shooting.

FEATURES

Superstructure

The superstructure subsystem comprises two systems, the elevator and pivot, which are used to perform scoring tasks. To orchestrate them properly, there is additional logic to ensure they never collide with each other or the Reef.

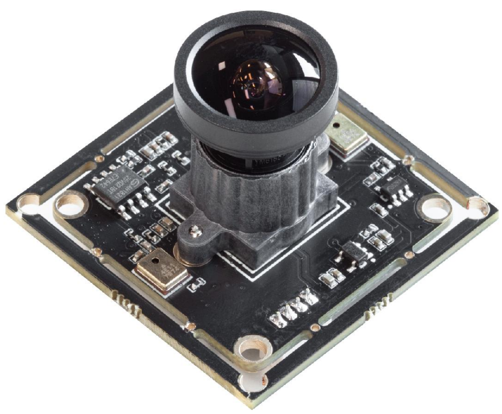
Automatic Alignment

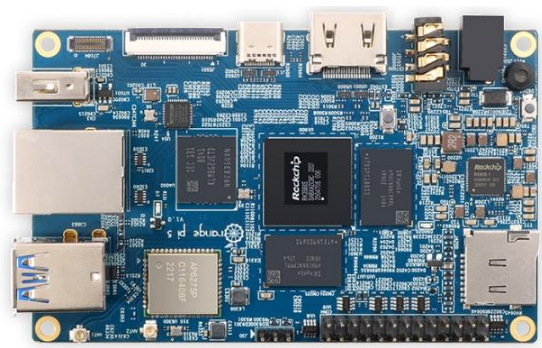
To decrease cycle times and improve reliability, we implemented automatic alignment to most of the tasks in the game, including Reef scoring, Algae pickup, Coral intaking, Processor scoring, and Net scoring.

1. Pose-based alignment: We utilize our pose estimation systems to know the position of the robot and automatically drive to target positions. The robot will also drive in straight automatically to avoid rubbing the bumper against the wall.
2. Position-based selection: Instead of having a new button for every possible position, the robot will align based on whatever target is closest. For example, to align with the Reef, drivers just have to drive up to the desired side before aligning.
3. Driver adjustment: The drivers have controls that let them adjust the target of the alignment if it is misbehaving during a match, allowing them to keep lining up accurately without having to regress to manual control
4. Smart control scheme: All of the automatic commands have manual variants that allow the drivers to pose the superstructure and drive up manually when things go wrong. These poses are on the same buttons, which means the drivers have less controls to remember. Everything is controlled using a "Dead man's switch" which improves safety and gives the drivers a way to easily cancel alignment

SYSTEM ARCHITECTURE

We run our own custom vision pipeline using Arducam cameras and Orange Pi 5's to detect AprilTags on the field and find the absolute position of the robot on the field. This system is highly reliable and redundant and will automatically reconnect cameras if they go down.

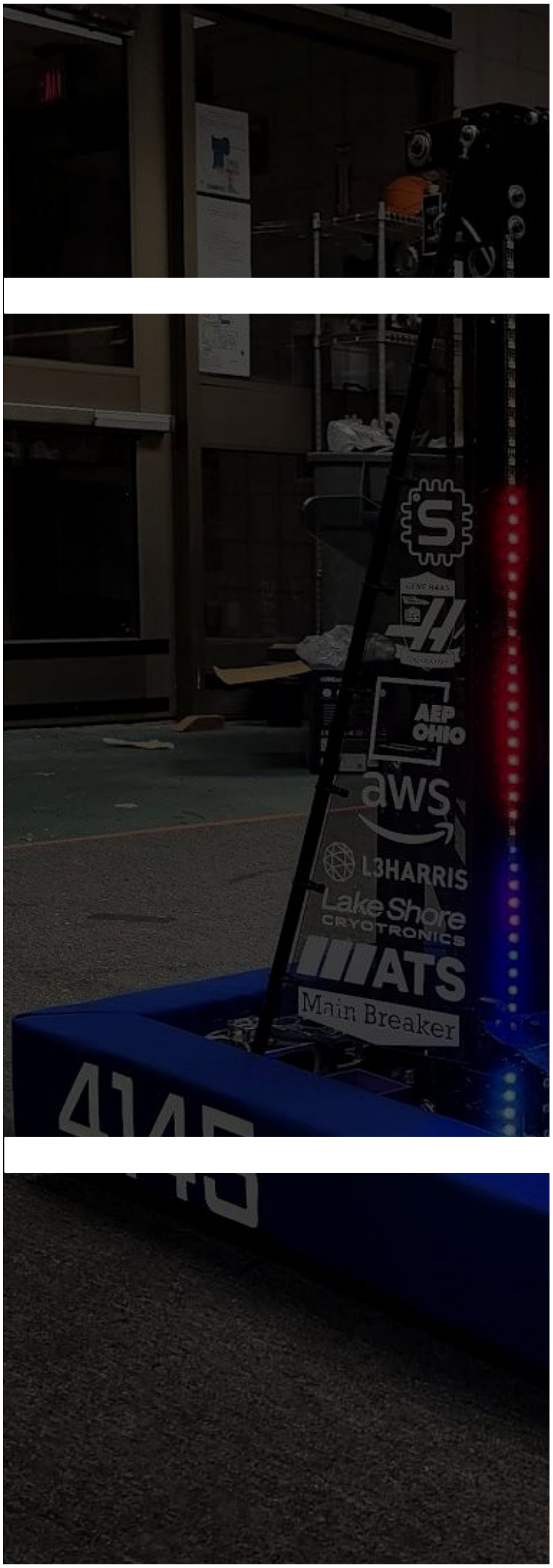




The vision pipeline runs separately from the robot code on each coprocessor, and sends positional data to the robot code. The code then factors the tag detections from the cameras into a Kalman filter along with the encoder odometry from the swerve drive to get an accurate reading of the robot's position. The filter also weighs sensor results using results from our empirical tests to negotiate the best position and discard bad data.

HUMAN INTERFACE

Apollo is controlled by one Xbox Pro Controller and a Logitech Extreme 3D Flight Stick. These controllers give us the best layout for driving swerve, while also giving us enough buttons to complete all of the necessary tasks.


AEP
OHIO
aws
L3HARRIS
Lake Shore
CRYOTRONICS
ATS
Main Breaker
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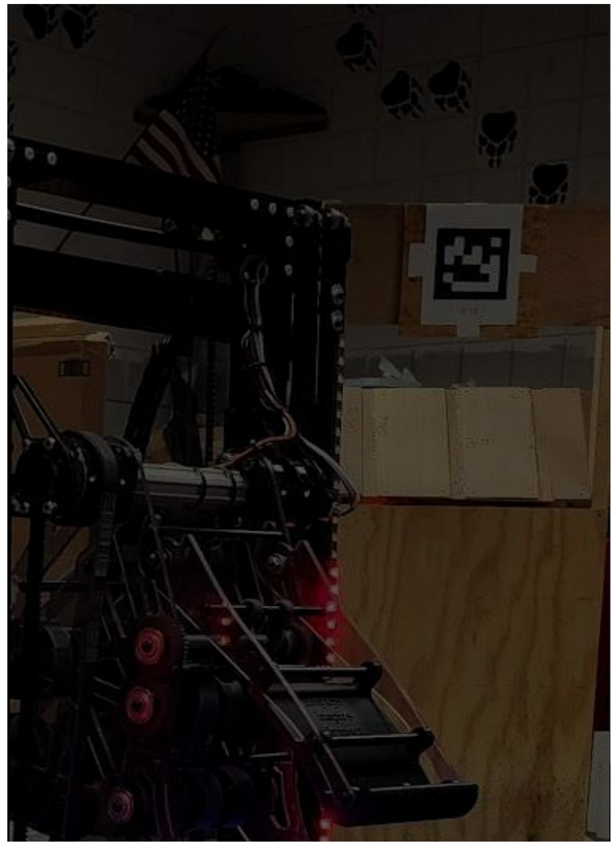


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