
HYPERION
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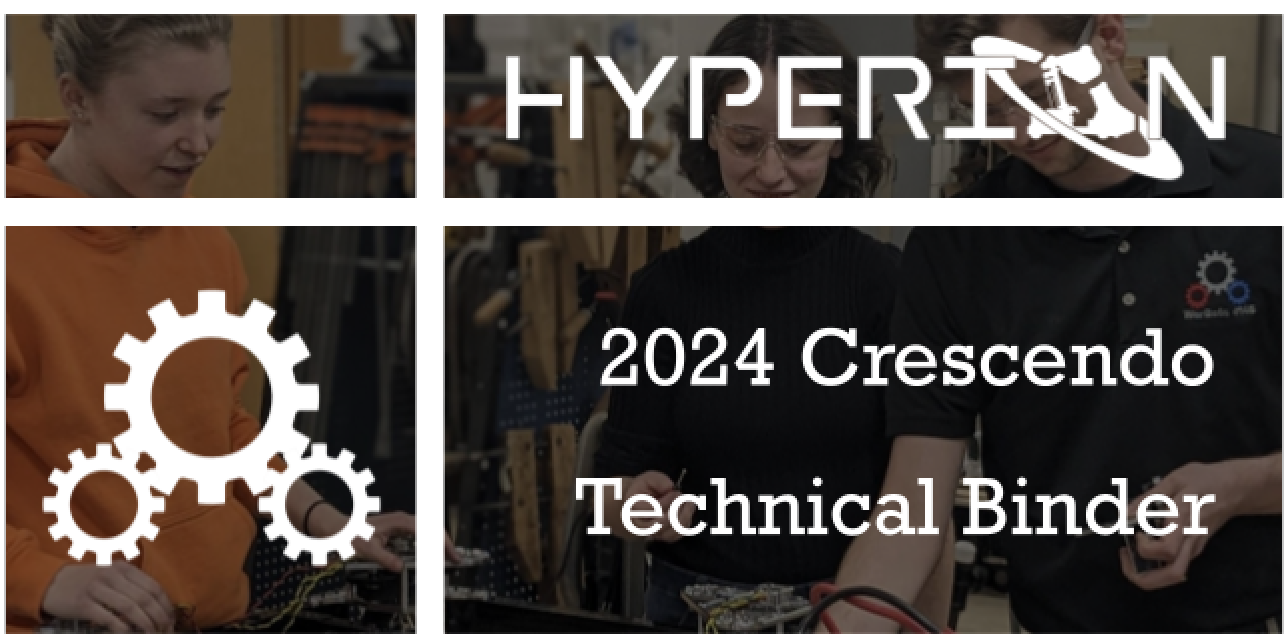
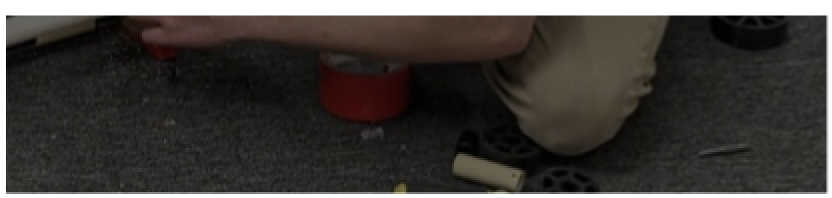

HYPERION
2024 Crescendo
Technical Binder

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 2024 FRC Season: Crescendo.

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 2024 *FIRST* Robotics Competition season.

The WorBots are proud to present our 2024 Robot: **Hyperion**



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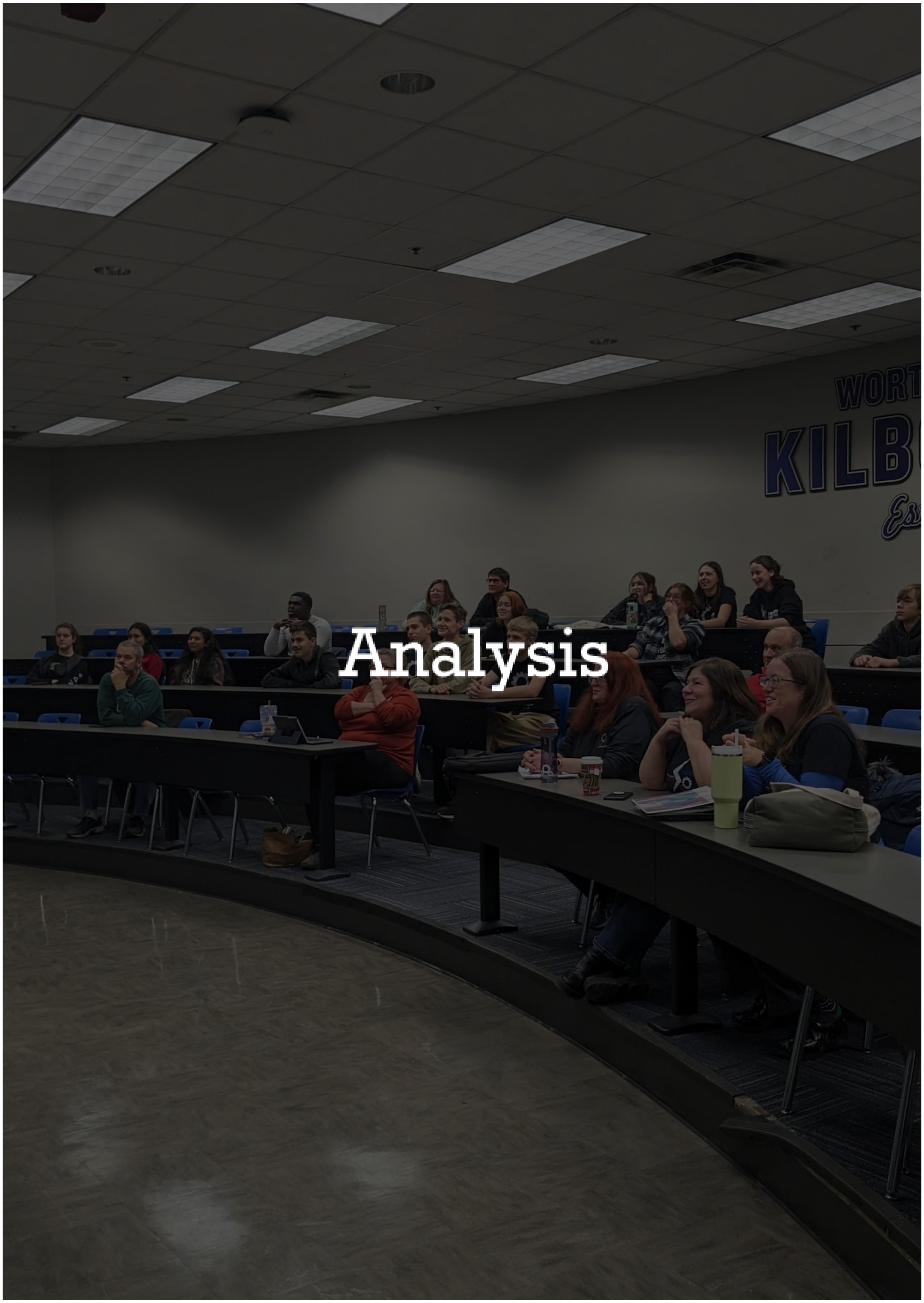


Analysis

GAME ANALYSIS

Crescendo is a complex game with multiple options to score. The main route is by scoring notes into the speaker, but this is also assisted by placing notes into the amp off to the side. In order to win a regional, we decided that the following must be accomplished:

Qualifications

- Earn as many ranking points as possible. The more ranking points earned, the higher ranked our team will be allowing for more flexibility in choosing our alliance partners in playoffs

Playoffs

- Maximize our score while also minimizing the score of the opposing team in order to win each match

Our goals are set up so that scoring points will lead to earning ranking points.

Qualification Match Strategy

Ranking points are awarded as follows: 2 for winning a qualification match, 1 for scoring 18 notes in the speaker/amp, and 1 for scoring 10 points on the stage with two robots on the chains.

- Score early in the amp and choose coopertition to lower the ranking point threshold for the melody to 15
- Score at least 10 notes every single match to lower on dependence on other teams' ability
- If other teams are able to consistently score notes in the speaker, we will keep the amp full so points are maximized and the threshold can be lowered, giving us an easy chance at a ranking point
- Climbing is not a priority, as the difficulty to earn the ensemble ranking point outweighs the reward. Instead, the priority during the endgame will still be on scoring in the speaker/amp as much as possible and parking under the stage

Assuming that our robot can consistently meet the aforementioned criteria, we increase the chances of winning the match and achieving at least 1 other ranking point, thus granting a high likelihood of earning at least 3 ranking points per match.

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:

- Maximizing scoring notes in auto when items have increased score
- Focus only on shooting notes into the speaker and let our alliance members perform other duties

GAME ANALYSIS cont.

Subsystem Strategy

Drivetrain

- ☼ Swerve drive is omnidirectional and allows for faster cycles and higher maneuverability to avoid opposing defense
- ☼ Low center of gravity to prevent tipping during high acceleration maneuvers
- ☼ Able to accurately and quickly aim shooter by rotating the chassis while on the move

Intake

- ☼ Touch it, own it, secure it. Fast and reliable intaking is critical to improve cycle times.
- ☼ Polycarbonate rollers with friction tape provide optimal friction to swiftly load notes and reduce weight
- ☼ Under the bumper intake reduces moving parts, and eliminates risk of damage to intake.
- ☼ Reliability. >95% accuracy in both intaking and delivering notes

Elevator

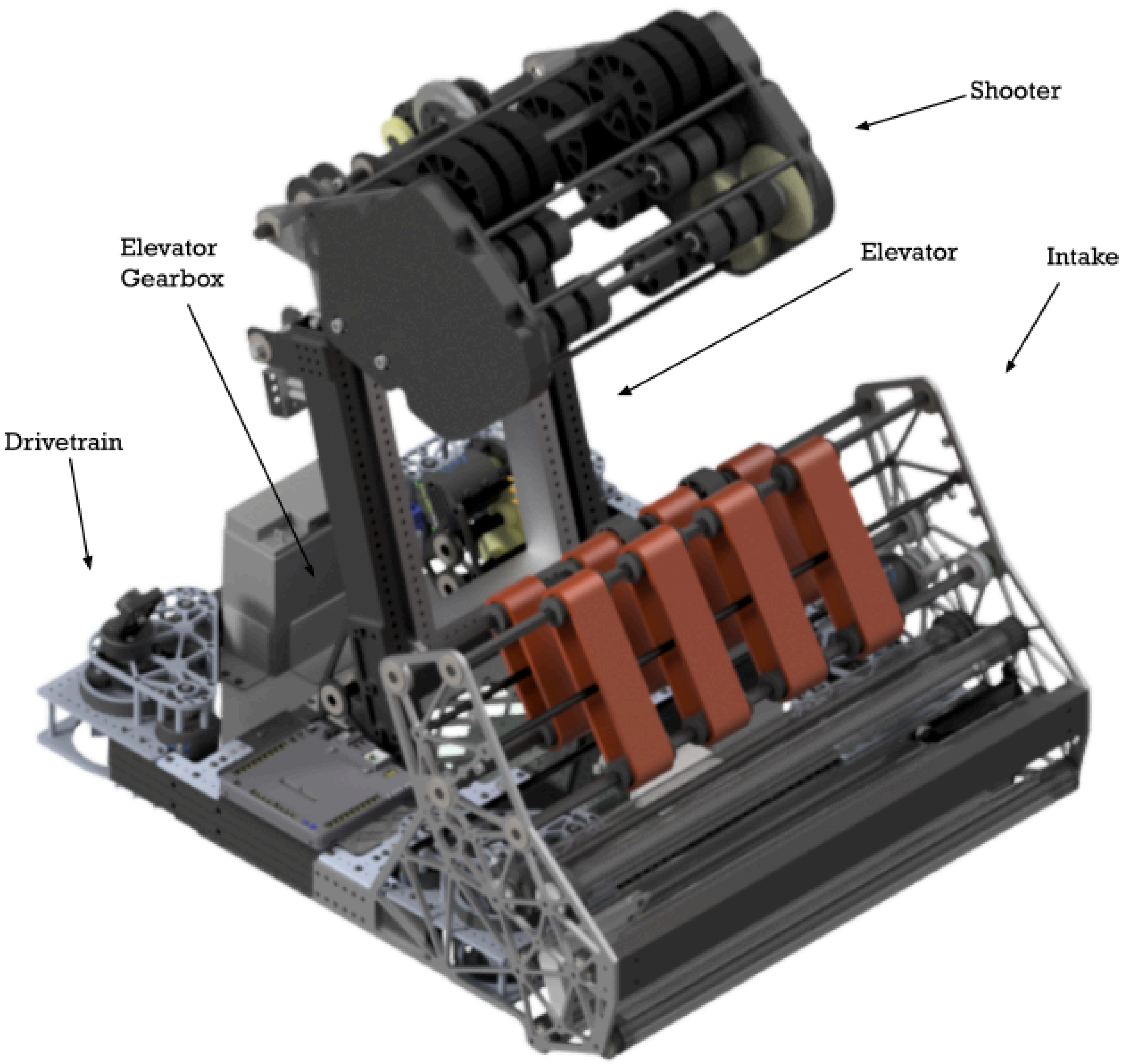
- ☼ Fast and reliable two stage elevator allows for amp scoring, reaching maximum extension in less than 0.75 seconds.
- ☼ Strong, custom gearbox to provide enough torque and power to move the shooter

Shooter

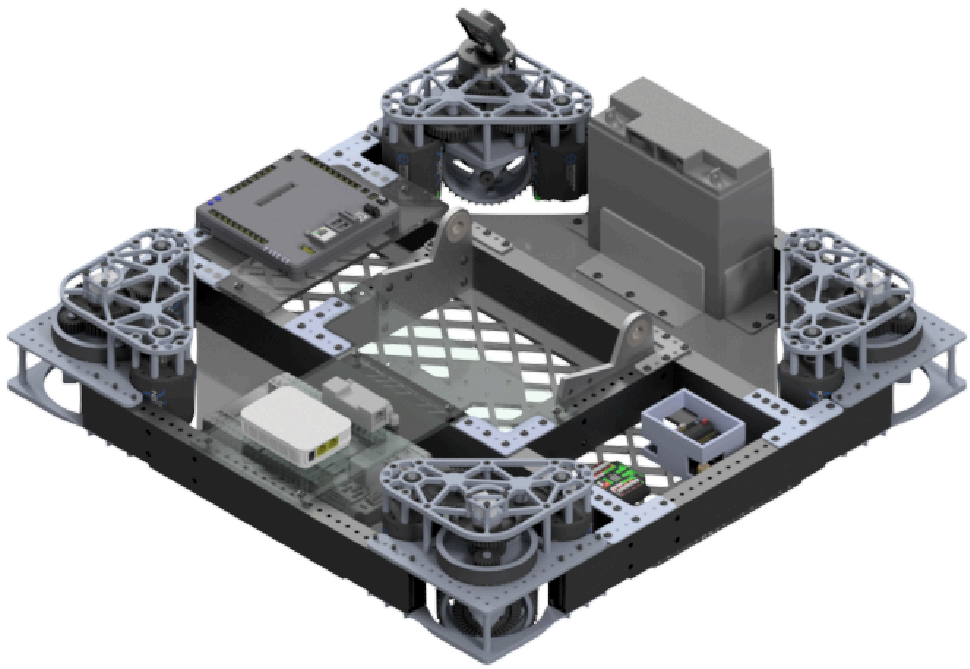
- ☼ Consistently shoots the note into the speaker from various positions on the field within the alliance wing
- ☼ Powerful enough for long shots into the speaker and able to shoot the note into the trap, with adjustable speed depending on the type and position of the shot
- ☼ Variable angle allows for amp scoring in less than 1 second
- ☼ Lightweight to allow for quick rotation and to reduce the chances of tipping


Robot Design

HYPERION



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.

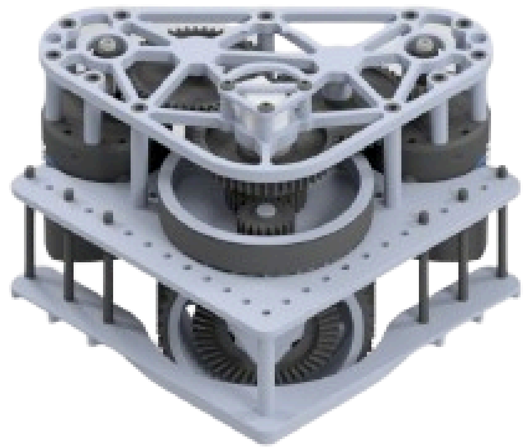
Chassis

- REV MaxTube 2 in. x 1 in. x .125 in. aluminum tubing makes a lightweight, but durable structure
- Drivebase is 26 in. x 26 in. to minimize robot footprint.
- Swerve modules mount directly to the chassis in the standard configuration to prevent notes from getting stuck under the robot

Base Plate

- 26 in. x 26 in. x 0.25 in. 6061 aluminum 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 6.12:1 L3 gear reduction

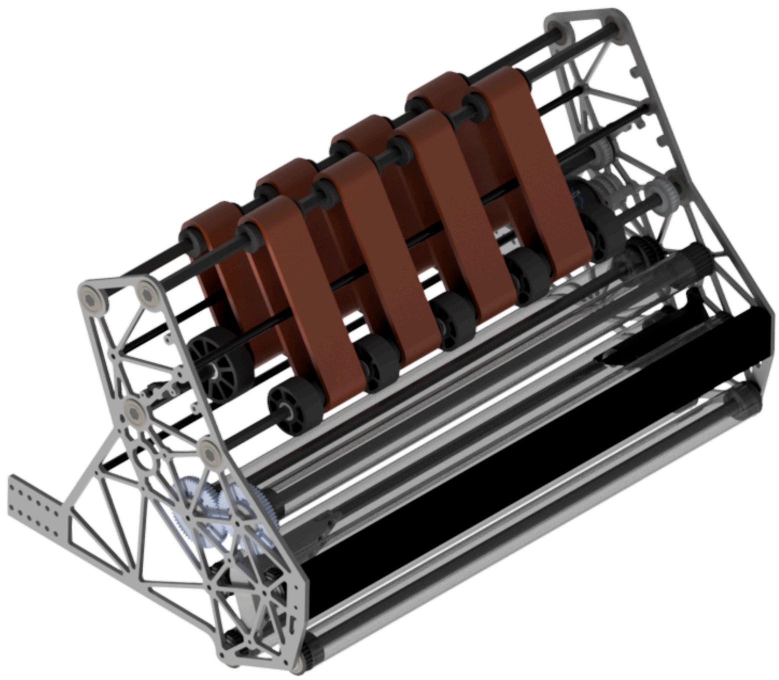
2 Kraken X60 Brushless Motors

- 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

INTAKE



The intake pulls in notes as soon as it touches them, allowing for faster cycle times and a quick pickup for drivers. Notes rapidly move through a series of rollers, belts, and wheels to position correctly in the shooter for an accurate shot. The intake must work every time, as one failure, break, or jam prevents the robot from being offensive for the majority of the match.

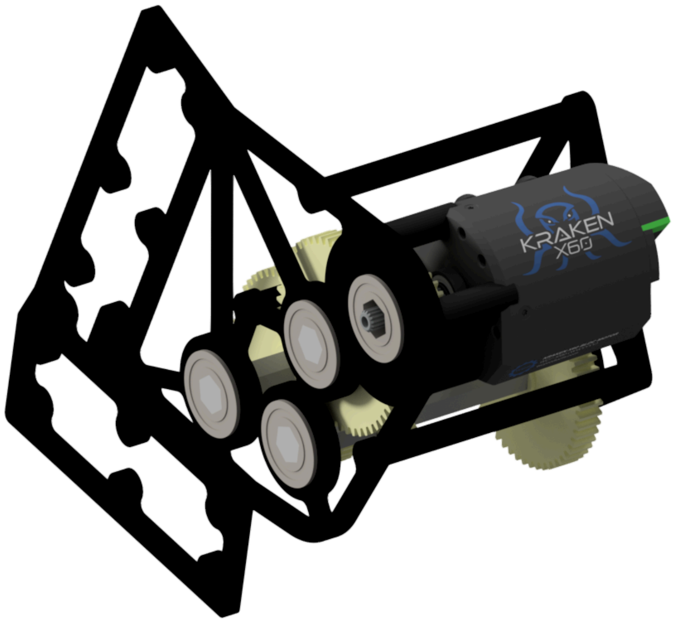
Structure

- ☼ Weight-reduced side plates provide a durable structure while staying lightweight
- ☼ Frame design allows the note to enter from various angles and positions.
- ☼ Under the bumper intake removes the need for extension and retraction, which saves weight and allows for faster cycle times

Rollers and Belts

- ☼ A set of lower grip-taped polycarbonate rollers acquires notes, feeding them through other un-taped rollers and polyurethane belts for handoff to the shooter

ELEVATOR GEARBOX



This custom gearbox system utilizes a Kraken X60 motor driving a set of gears to smoothly extend the elevator as it translates, and give the elevator enough power to lift the robot and prevent significant backdrive.

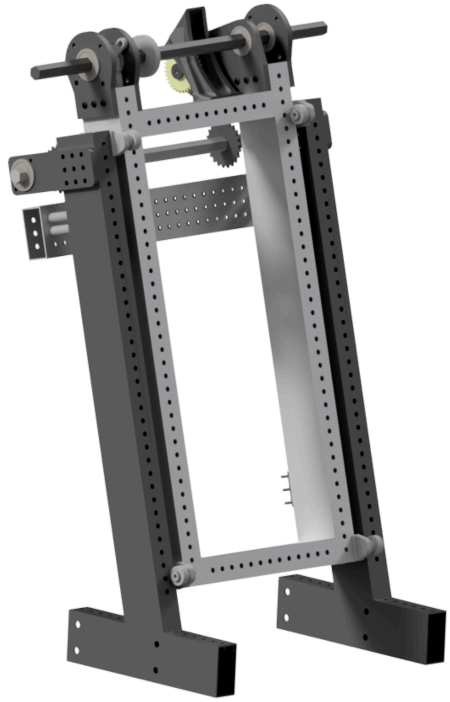
Gearbox System

- A 27:1 gear reduction creates 189 Nm of torque, propelling the elevator with ease

Structure

- ¼ in. 6061 aluminum plating attached via. ⅜ in. aluminum standoffs
- Open design allows for ease of repair and weight reduction
- An aluminum ThunderHex axle connects the elevator driving sprockets to the gearbox, providing smooth motion for efficient amp scoring

ELEVATOR



The elevator utilizes a cascade lift to provide maximum speed in extension, since every element moves in unison. A curved guard helps to protect the pivot from damage. The elevator has a strong frame to support the whole shooter subsystem while being lightweight to increase speed and the amount of power needed to move.

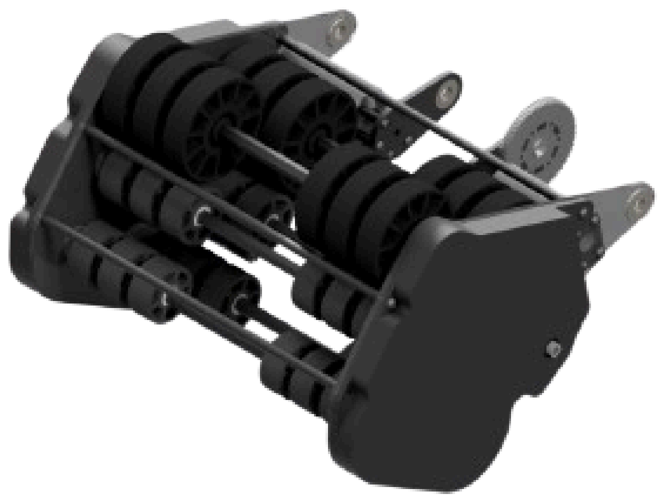
Stage

- ☼ The mounting point for the shooter pivot, which develops multifunctionality
- ☼ Powered by the elevator gearbox through #25 chain, which is attached on the rear of the frame
- ☼ Fast motion allows for easy positioning while scoring in the amp

Frame

- ☼ 2 in. x 1 in. aluminum tube creates a strong foundation, keeping the elevator steady even when fully extended; vital to support the weight of the shooter

SHOOTER



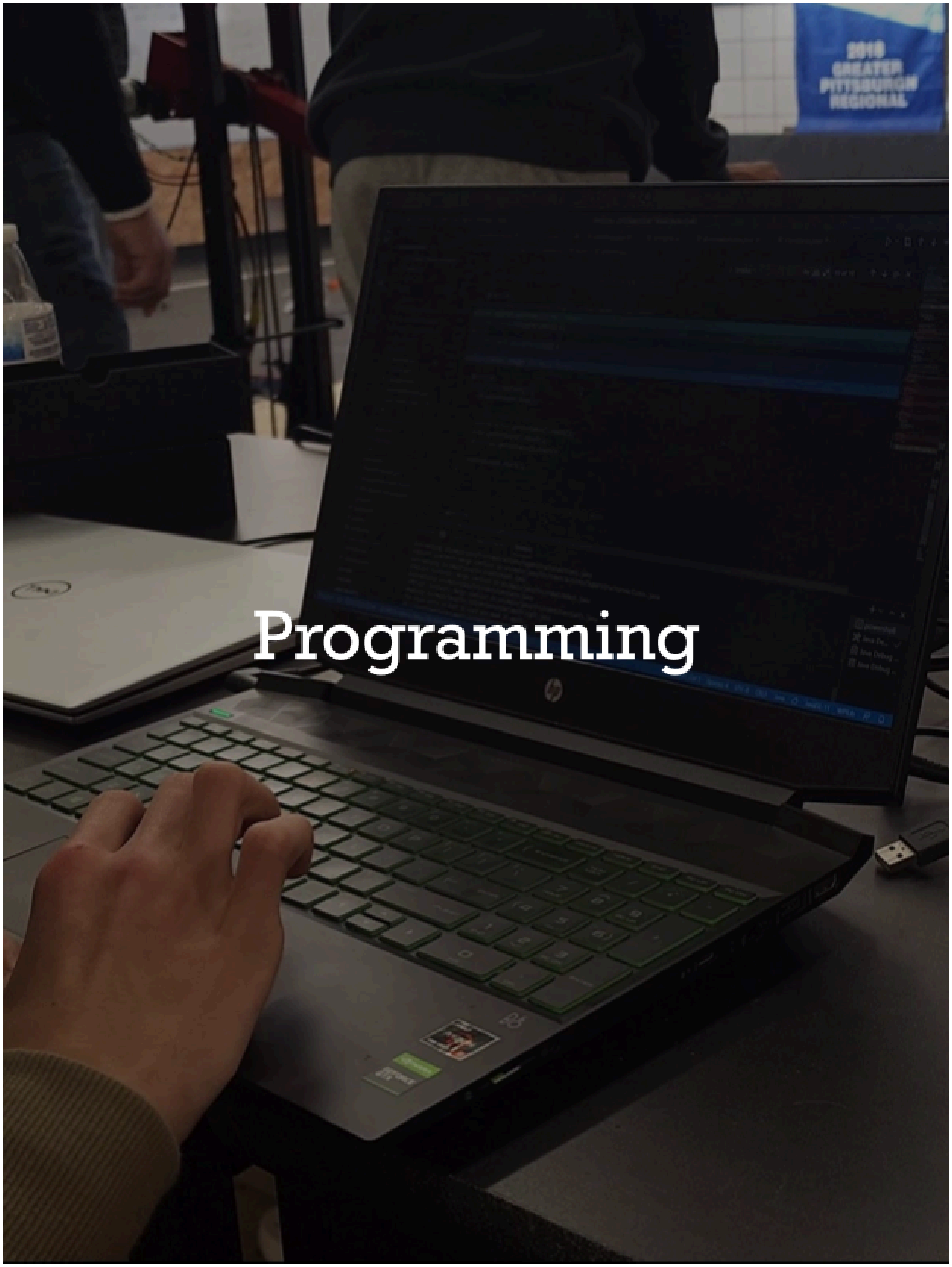
The shooter pivots on an axle connected to the elevator, allowing it to position for a variety of shots. Six sets of rolling compliant wheels swiftly launch the note from the shooter.

Wheeled Shooter System

- 4 in. diameter 60A compliant wheels get to high speed for consistent and powerful shots
- Small wheels hold notes in place, and start the shot once the large wheels reach speed
- Uneven wheels help to stabilize shots when pulling a note

Frame and Pivot System

- The shooter is connected to a thunderhex axle which acts as a pivot, and is mounted to the first stage of the elevator. A Falcon 500 motor powers this pivot using a 120:1 gear ratio, allowing for stable rotation while maintaining speed
- Polycarbonate sides and aluminum standoffs maintain a lightweight, sturdy shape
- Gears and belts are covered to prevent injury, wire damage, and system wear



Programming

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.

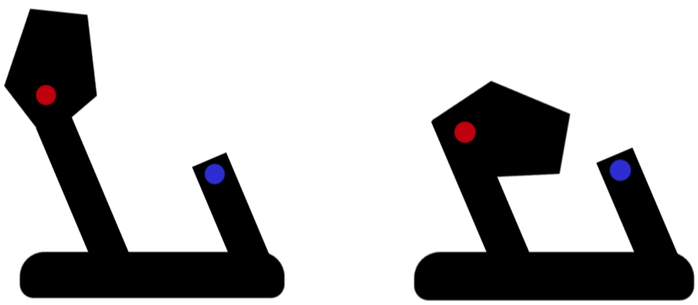
PIDs

PIDs, or proportional, integral, and derivative controllers, are used in a number of places on *Hyperion*. 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 shooter pivot and elevator 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

Handoff and Delivery

To facilitate the motion of notes within our robot, we designed and implemented a smart delivery system that automatically and intelligently moves game pieces through our intake and shooter. We first diagrammed a finite set of states that our system would act on.



S1 S2

In state S1, our shooter is out of position and will not allow proper delivery. In this state, we only intake a piece up to the first blue sensor so that it doesn't fly out of our intake and can be held by the drivers. In the S2 state, our shooter is in the correct position for delivery. Here, the game piece is brought all the way up to the second red sensor so that it is ready for shooting. This entire system is controlled by just one button on our driver's controller, which vastly simplifies their operation of the robot.

Contextual Shooter Control

Another smart control system in our robot is the contextual operation of the shooter wheels. All under one button, the drivers are able to automatically spin the wheels to the correct speed for the desired operation. The system is able to detect the current state of the shooter pivot and elevator to infer driver intent and perform the correct action, such as shooting at a slow speed for amp scoring, or intaking through the shooter wheels for source pickup.

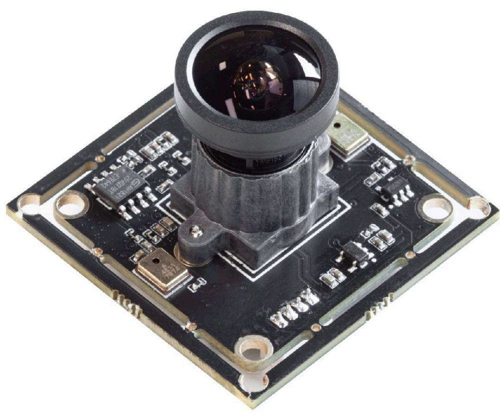
Automatic Targeting

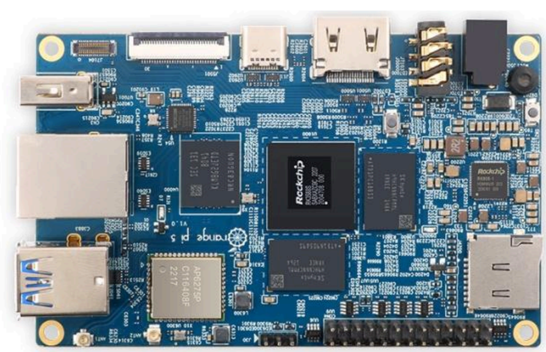
When designing our robot, we quickly realized that drivers would be unable to manually target in a quick and accurate manner. To alleviate this problem, we brought all of the control systems on the robot together to automate this targeting and shooting process.

1. PID Control: We utilize the existing PID control loops in our subsystems and commands to ensure accurate control of the systems we need for our shots
2. Ranging: Using a tested and tuned lookup table, our distance to the speaker is calculated and used to determine the best possible angle for our shooter to make the shot
3. Robot Targeting: The robot automatically rotates so that it is facing the speaker when in targeting mode. In addition, we can modify the goal position so that the robot aims further back or forward from the speaker. This can increase our accuracy for different types of shots.
4. RPM Control: While longer shots need more power to get the note to go far enough, we found that high speeds at close ranges would make notes bounce out of the speaker. To mitigate this problem, we automatically scale down the shooter speed as we get closer to the speaker.
5. Pose Prediction: To increase response times and compensate for momentum while moving, our targeting system applies our current speed to our current pose to predict where the robot will be in the future and uses that modified pose for calculations
6. Driver Control: While targeting, our drivers are still able to move the robot around the field. However, we automatically reduce their speed when they get close to the target so that our targeting system can be more accurate.
7. Driver Feedback: So that our drivers can know when to take the shot, the targeting system calculates a confidence level based on parameters like distance, speed, and shot angle. This confidence is then displayed to the drivers using the onboard lights so that they can be sure they are making shots properly.

VISION

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.

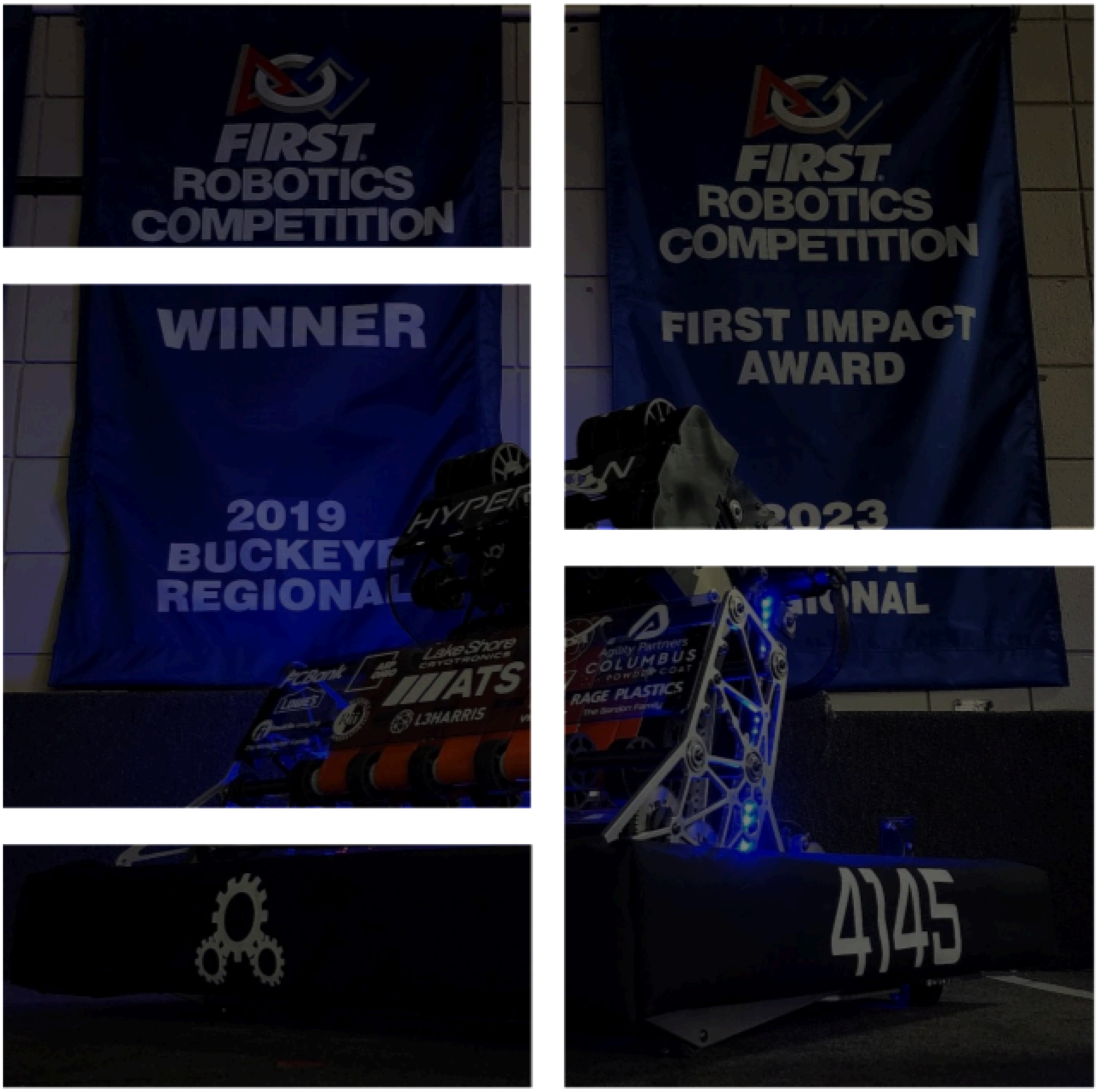




The vision pipeline runs separately from the robot code on each coprocessor, and sends positional data to the robot code. The code then factors the tag detections from the cameras into a Kalman filter along with the encoder odometry from the swerve drive to get an accurate reading of the robot's position.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

HUMAN INTERFACE

Hyperion is controlled by two Xbox Pro controllers. These controllers give us the best layout for driving swerve, a flexible and modular design, and a high level of reliability.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