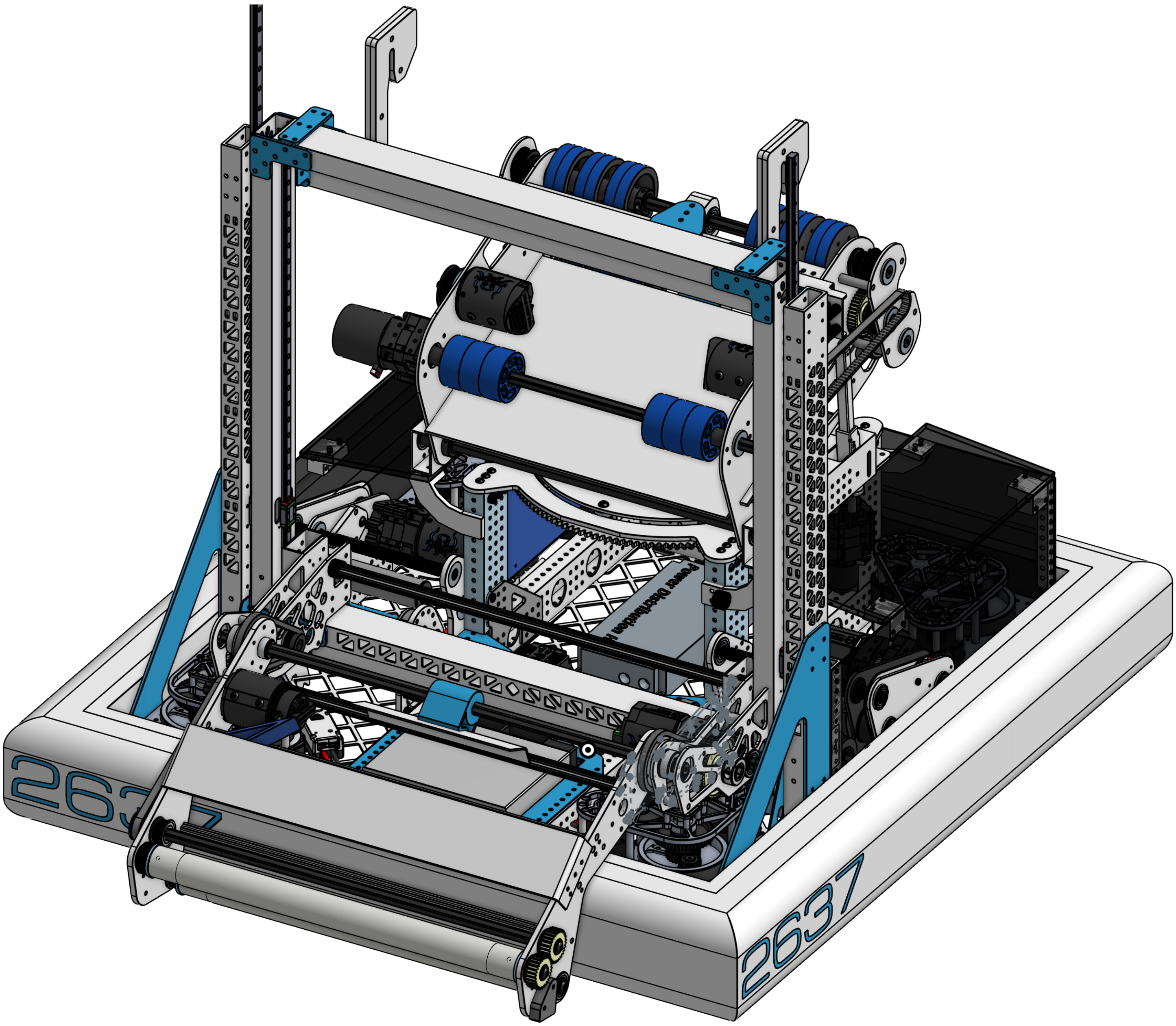
2024 Crescendo Technical Binder

2637 Phantom Catz

Los Angeles Regional Version



FORTE

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1 Introduction

1.1 Purpose

This Technical Binder explains the process and choices from our technical subteams that resulted in **FORTE**.

1.2 Acknowledgements

This was 2637's first Technical Binder. We referenced various teams' technical binders for inspiration. Thank you especially to teams 254, 2056, and 2910 (listed numerically).

Thank you additionally to teams who publicly their progress - through OpenAlliance or other – this year, as it helped inform our robot decisions.

2 Engineering Process

Processes result in repeatable consistency and effective improvements each year. Team 2637's Engineering Process ensures consistent results and improvements each year.

- Organization
  - Engineering Project Manager oversees and plans for every Technical Subteam
  - Pre-emptive Engineering Schedule is generated in Gantt Format before Kickoff.
  - Members are assigned individual tasks via Trello.
  - Two robots are built – SN1 and SN2 – and each has multiple subsystem versions to generate continuous improvement and testing.
- Strategy & Systems Design
  - Analyze different strategic approaches to the game during kickoff and develop an IAS (Ideal Alliance Strategy), a strategy we hypothesize to see at the Final matches of the World Championship.
  - Define our role in the IAS and generate system requirements which support the role
  - Develop ConOps (Concept of Operations) for each robot mechanism using system requirements
  - Develop a playbook which compiles viable strategies for different alliances, updating the strategies through scouting matches
- Robot Concept Selection
  - Teams draft mechanisms and robot concepts based on System Requirements
  - Mechanical Design selects promising concepts, then validates geometry via Kinematic Sketches and Crayola/Cartoon/Krayon CADs
  - Technical Leadership agrees on Final Robot Concept
- Prototyping
  - Mechanism Concepts are generated by team
  - Mechanical Design selects promising concepts
  - Mechanical Design determines "magic numbers" – the values that Mechanical Design needs for CAD and the values that drive the main point of prototyping
  - Mechanical Design and Manufacturing develop low-fidelity mechanisms to attain "magic numbers"
- Mechanical Design
  - Master-sketch contains all critical geometry, mitigating later interference/handoff problems
  - Assemblies derive master sketch geometry
  - Design Reviews provide feedback which is recorded in Version Update Documents

  - Design Communication (BOMs and Cutsheets) are generated to inform Manufacturing

- Manufacturing
  - Design Communication (BOMs and Cutsheets) are updated accordingly
  - Items are placed into labelled kitboxes to prepare for assembly

- Electronics & Pneumatics
  - Wiring diagrams to plan electrical layout and reduce wiring time

- Programming
  - Robot Programming
    * Collaborate with Strategy & Systems Design to tweak ConOps (Concept of Operations) for each robot mechanism based on programming limits/desires
    * Mechanism code split into Github branches
    * Code undergoes peer reviews and physical testing
    * Stable code is pushed to main GitHub branch for further testing
  - WebDev (Scouting App) Programming
    * Work with Strategy & Systems Design to detail necessary changes to Scouting App

- Testing
  - As subsystem version are created, each technical subteam generates feedback
  - Mechanical Design and technical subteams work to revise CAD to solve problems
  - Mechanical Design can discuss with Strategy & Systems Design to re-adjust System Requirements
  - At end of competition and year, team holds Lessons Learned to formally gather feedback in spreadsheet format

3 Strategy & Systems Design

3.1 Game Analysis

Crescendo's central game objective is to manipulate ring-shaped Notes and to score them onto various locations of the field, as well as to get Onstage by climbing on the chain.

The highest point value teleop objective is an amplified Speaker Note (need Amp and Speaker capabilities), and highest point value endgame objective is a Note in Trap (need climb and Trap capabilities). Meaning, to achieve our season goal of winning a regional, we must accomplish the following:

- Maximize number of notes scored while amplified
- Maximize alliance scoring potential to win matches
- Obtain as many ranking points as possible to rank highly and have freedom in selection to form an Ideal Alliance
- Minimize external dependencies (thus self-sufficient) in scoring capabilities to ensure ranking point obtainment in any alliance

Following our goals, we prioritized our ranking points as

- WIN (2): Completing a match with more match points than your opponent
- MELODY (1): At least 18 (15 if Coopertition Bonus) Amp & Speaker Notes
- ENSEMBLE (1): At least 10 Stage points and at least 2 Onstage Robots
- TIE (1): Completing a match with the same number of match points as your opponent

Thus, we formulated our IAS called SHH (speaker-hybrid-hybrid), where one robot solely focuses on the Speaker and the other two score both Amp and Speaker Notes. Identifying our role on the IA as a hybrid robot, we decided to pursue the following challenges:

- Scoring Notes into the Speaker
- Scoring Notes into the Amp
- Getting Onstage
- Scoring Notes into the Trap

3.2 System Requirements

Category	ID	Requirement
Intake	1	Robot shall be able to intake one unsupported note from the ground (no wall, truss, etc.)
Note Scorer	2	Robot shall be able to shoot into the speaker from anywhere between the Subwoofer and the Truss legs
Note scorer	3	Robot shall be able to align to scoring locations horizontally and vertically without manual input
General	4	Robot shall be able to self-align to scoring and source locations
Climb	5	Robot shall be able to hang on chain at any point independently
Note Scorer	6	Robot shall be able to score in trap
Intake	7	Robot shall be able to intake one note from source chute
Note Scorer	8	Robot shall be able to score in the amp
Note Scorer	9	Robot shall be able to shoot from the opposite side of the intake

4 Robot Concept Selection

Team 2637 explored various robot concepts before finalizing on our Final Robot Concept. Here are some concepts we explored:

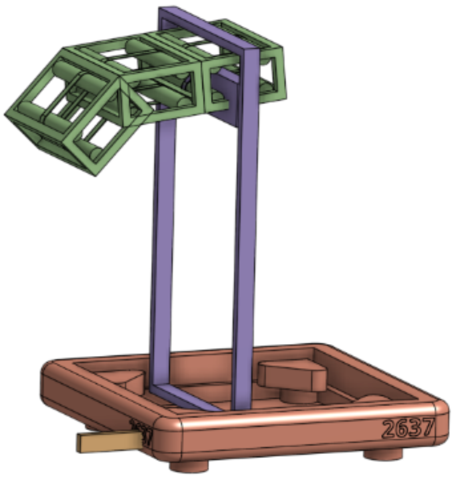


Figure 1: Concept A

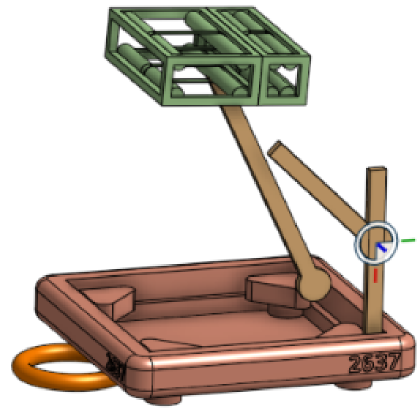


Figure 2: Concept B

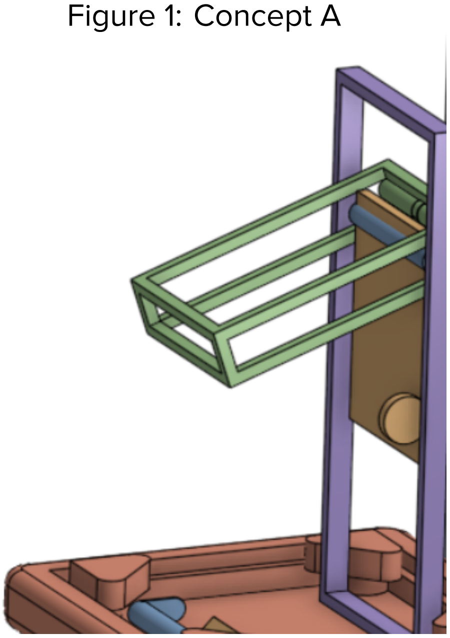


Figure 3: Concept C

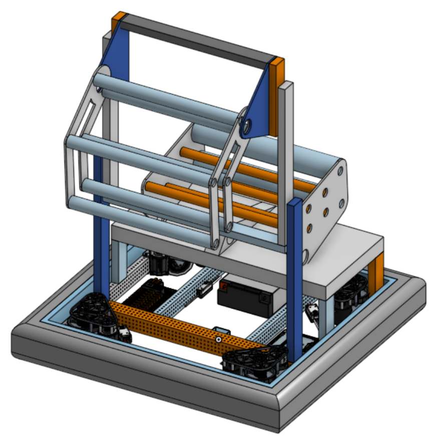


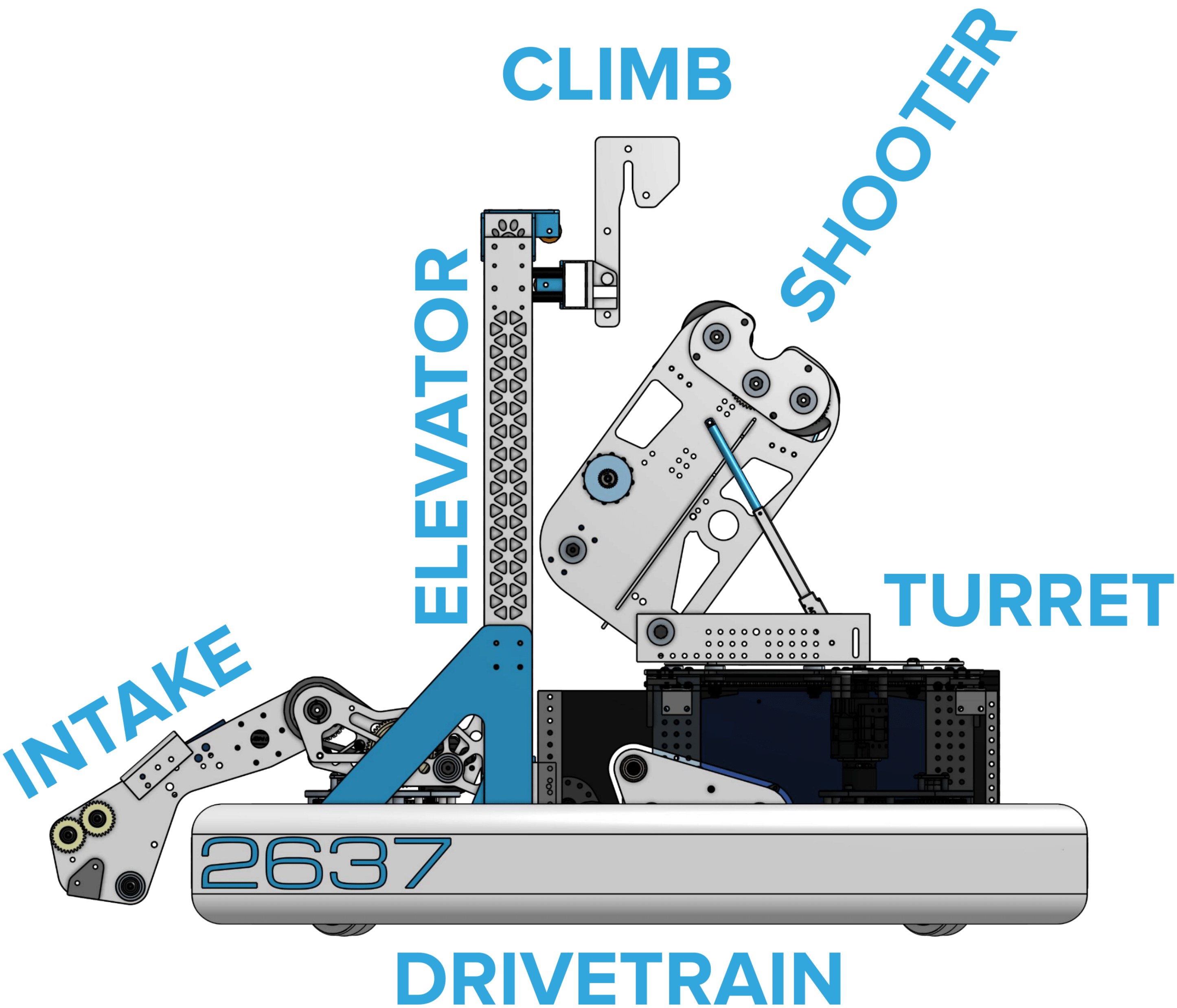
Figure 4: Concept D

Finally, we settled on our Final Robot Concept: Option D. Our Final Robot Concept was chosen because it:

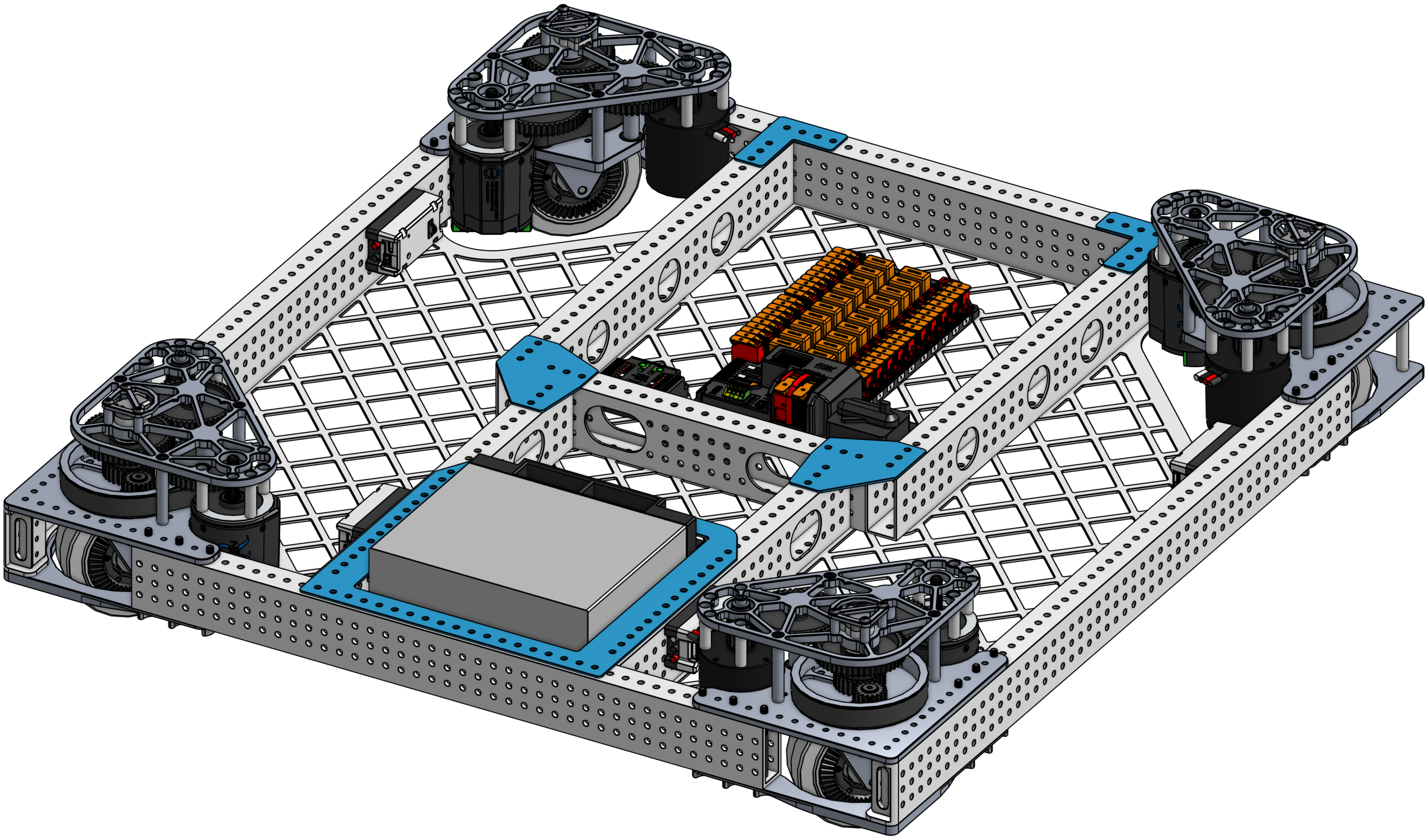
- Addresses all of our System Requirements
- Uses mechanisms concepts similar to ones we have used in the past – meaning more confidence in having them done correctly and on time
- Does not have singular points of failure

5 Mechanical Design

5.1 Subystem-labelled Robot



5.2 Drivetrain



The drivetrain lets us maneuver quickly and precisely to score points.

- **Powertrain**
  - SDS MK4i Modules
  - Kraken X60 Drive, Falcon 500 Steering
  - 16T Pinion Adapter
  - SDS Colson Adapters
- **Frame**
  - 29” by 30”
  - 1/8” Aluminum 6061 Outer Boxtubes (front tube is 1/16” to insert weights) and 1/16” Aluminum 6061 Interior Boxtubes
  - Extended side boxtubes via tubeplug for mounting
- **Electrical**
  - Battery mounted in front to shift CG to bottom front

5.3 Intake + Pivot

The intake lets us pick up notes from the floor and outtake them into the our shooter or the amp. Our pivot lets us position our intake for the ground pickup position, amp scoring position, and shooter handoff position. Our intake mounts to our elevator carriage which lets the whole subsystem move vertically.

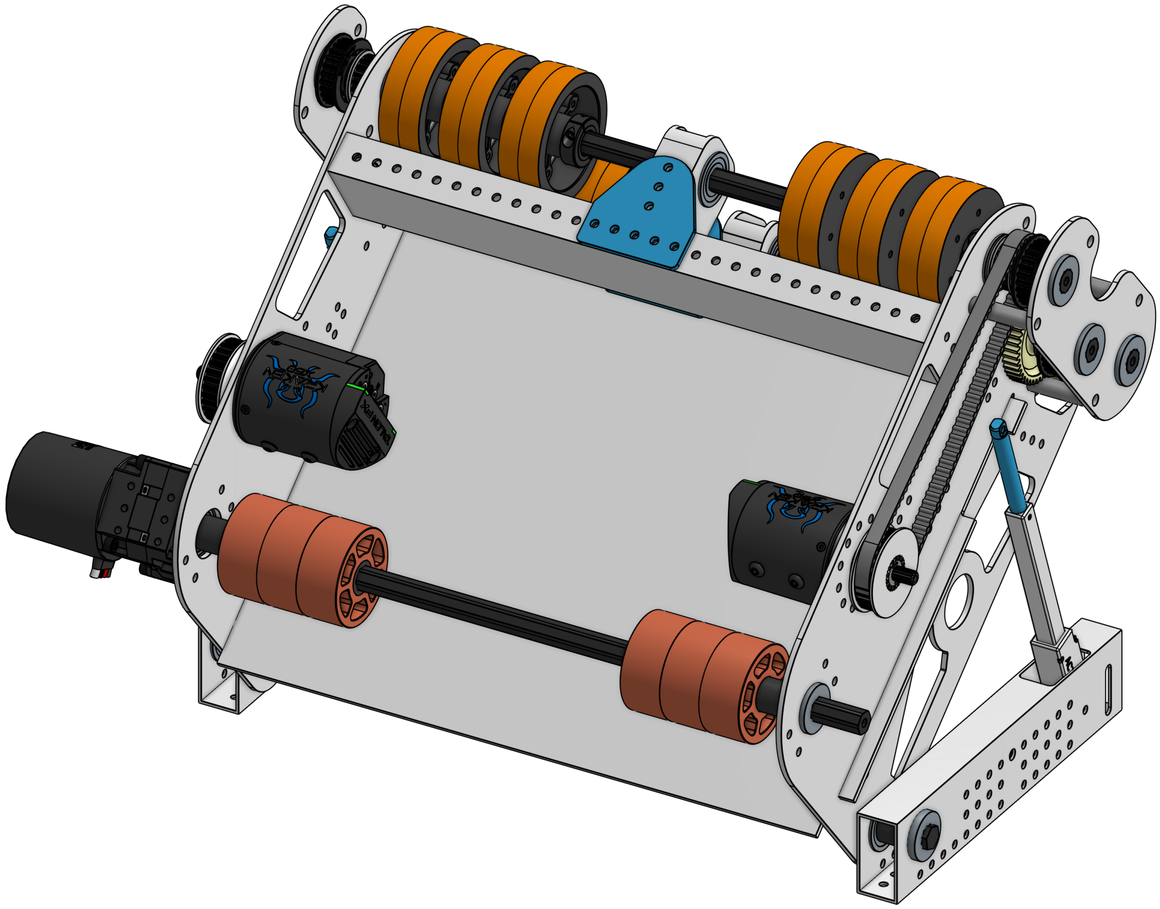
- **Powertrain**
  - Intake Rollers
    - 1 Falcon 500 with a 1:1 reduction
  - Pivot
    - 1 Kraken X60 with a 1:24.167 reduction
- **Mechanical**
  - Lightened, 1/8" Aluminum 6061 Main Plates
  - 1/4" Polycarbonates (for durability) arm
  - Polycarbonate rollers with outer silicon tubing is grippy but light

5.4 Elevator

The 2-stage cascade elevator lets us move our intake up and down. The minimum position places the intake in position for ground pickup, shooter handoff, and amp shooting. The max position places the intake in position for trap scoring.

- **Powertrain**
  - 1 Kraken X60 with a 1:16 reduction (various sized spools change linear line speed)
  - Dynemma pull-up and pull-down rigging to save weight, mirrored on each side
  - Cascade rigging for speed (various sized spools acoutn for line speed differential)
- **Mechanical**
  - Linear Rails (as opposed to traditional bearing blocks) for rigidity
  - Access holes designed for un-conventional assembly
  - Pocketed 1/8" boxtube and plain 1/16" boxtube provides light yet strong support
  - A-frame gussets extend to front of drivetrain boxtubes (with inset Tubeplug) for increased support.

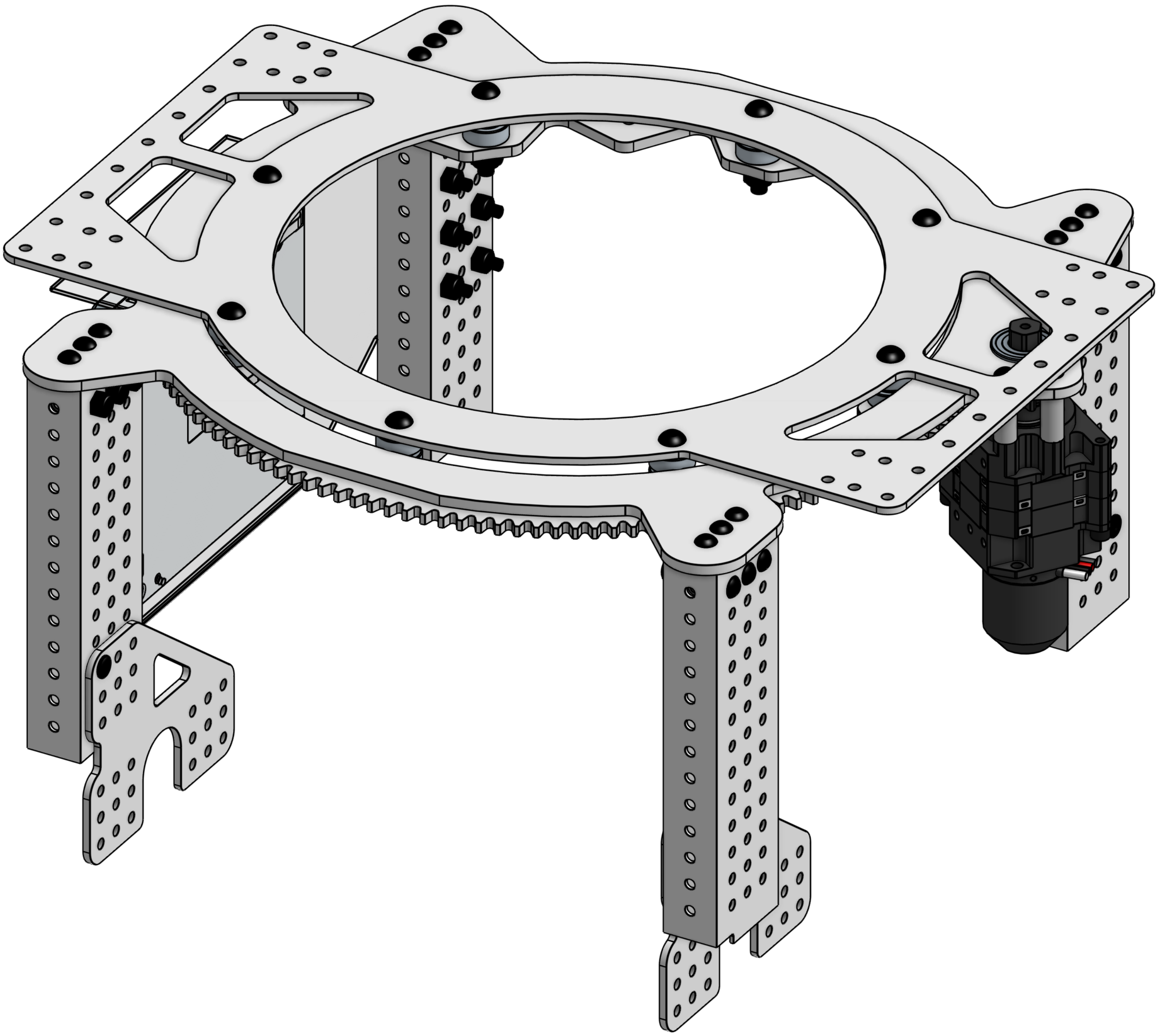
5.5 Shooter



The shooter lets us score notes into the speaker from roughly half field via a pivot. A load/feed roller ensures a consistent feed into the shooter flywheels. A top-and-bottom flywheel setup ensures consistency. It is mounted on the turret, allowing us greater scoring freedom.

- **Shooting**
  - Feed/Load roller
    - 1 NEO with a 1:3 reduction
    - 2.25" OD, 40A Durometer wheels
    - HDPE film-wrapped whiteboard for low friction 'floor'
  - Flywheels
    - 2 Kraken X60s each with a 1.667 reduction
    - 3" OD, 40A Durometer wheels
    - Independently powered sides let us customize induced note spin
- **Pivoting**
  - 2 100mm Linear Servos
  - 20° to 54° angle range

5.6 Turret



The turret lets the shooter angle towards the SPEAKER from $\pm$ 120 °. The design mimicks both our 2022 turret and WCP's GreyT Turret.

- **Powertrain**
  - 1 NEO 550 with a 1:126 reduction
  - 140 tooth 10DP gear
- **Mechanical**
  - Bearing stacks (2 0.75" OD bearings) ride on a metal rim, providing smooth motion.

5.7 Climb

The climb winches up to score climb points and locks into place to prevent sliding down after the match. It also positions us to score in the Trap. There are 2 gearboxes and 2 hooks in total: one pair per robot side. Items listed below are per side (double them to attain total).

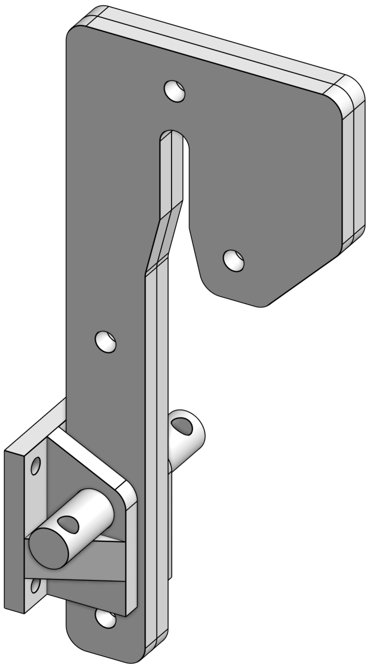


Figure 5: Hook Deployment

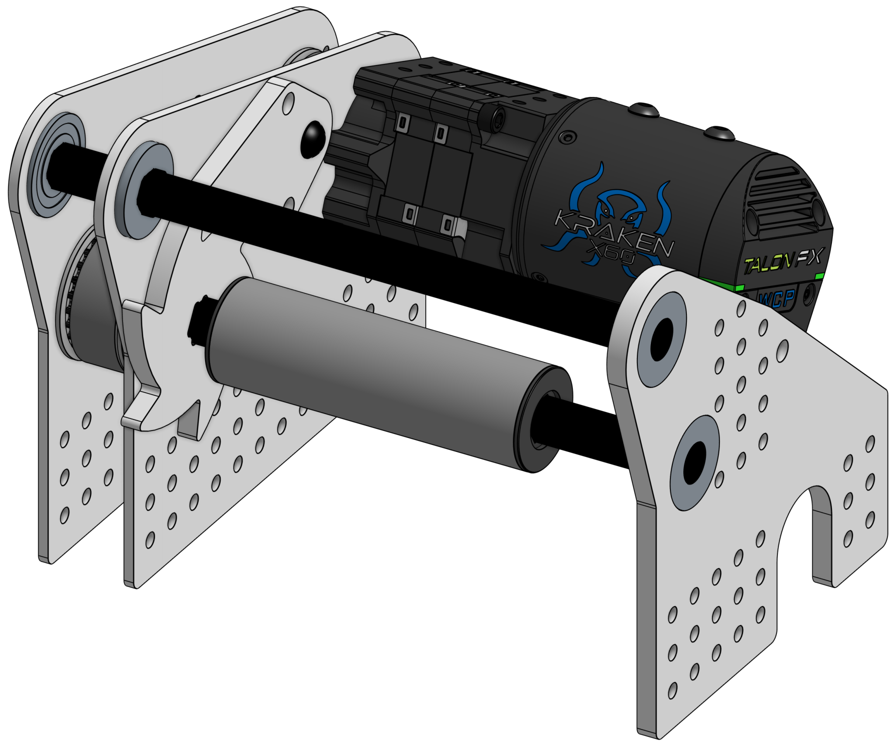
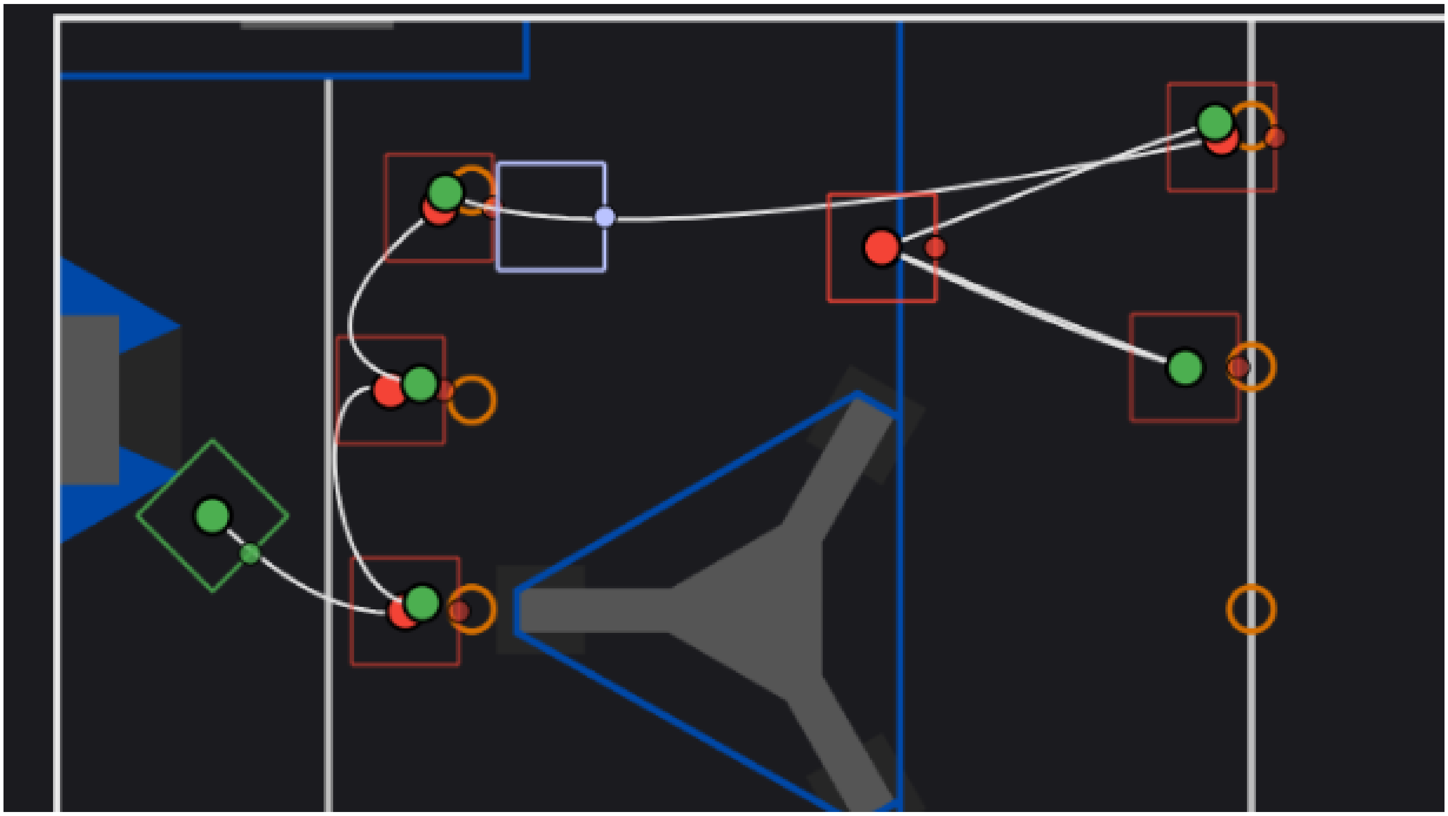


Figure 6: Gearboxes

- **Gearboxes**
  - 1 Kraken X60 with a 1:25 reduction
  - Custom ratchet and pawl prevents backdriving
- **Hooks**
  - Polycarbonate hooks latch onto 'thin' chain face, preventing sideways slippage
  - 2-pin (major and minor) locking system
    * Major pin holds hooks vertically
    * Major pin pushed inwards via spring
    * Minor pin (not pictured) holds main pin horizontally
    * Dyneema retraction removes minor pin, allowing major pin to free, allowing hooks to deploy

6 Robot Programming

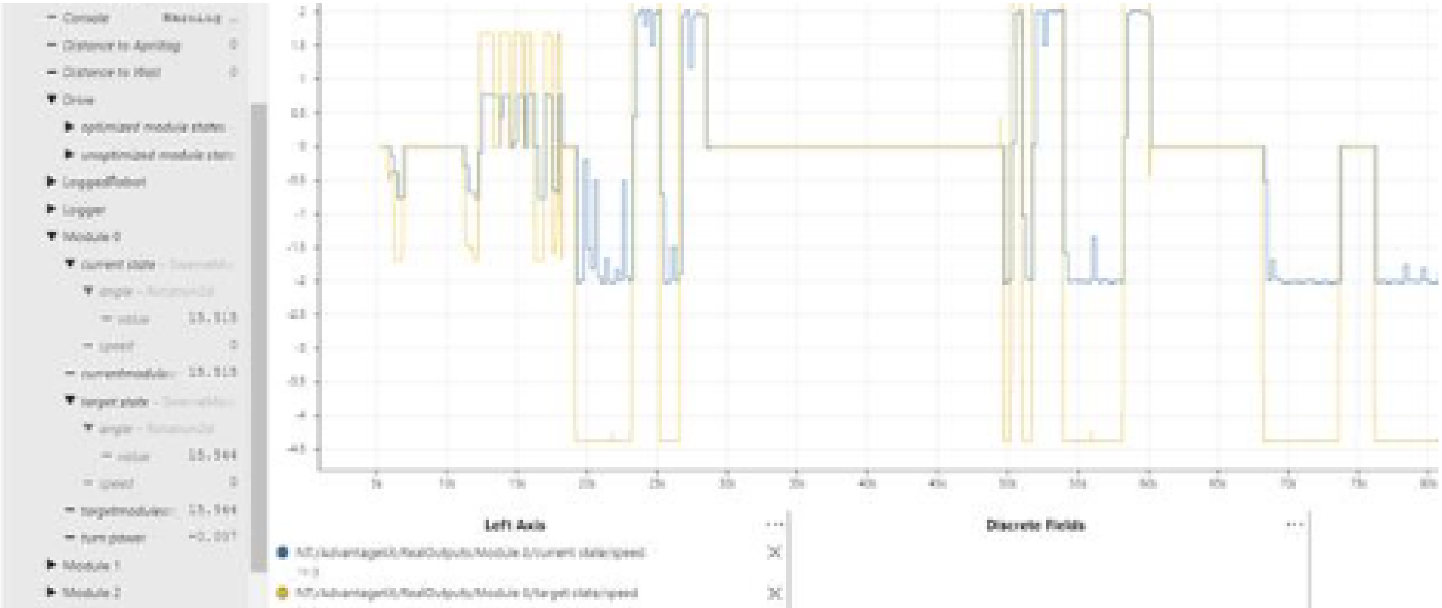
6.1 Autonomous



FORTE uses AprilTag pose estimation and drivetrain odometry to follow a pre-made/automated trajectory to orient and manuever to field positions.

- **Pathing**
  - Pre-made Paths are generated in PathPlanner
  - Automated paths are generated on the fly by inputting desired positions and constrains to avoid field elements
- **Path Execution**
  - Holonomic drive controller calculates target robot vector based on auton path PID controller compares target and actual robot positions to update drivetrain

6.2 General



FORTE uses advanced feedback loops to control itself.

- **Superstructure/Advanced Logging**
  - Command-based architecture with modified subsystem organization for Advantage Kit graphics and csv exporting.
  - State ”package to subsystem” based superstructure maps buttons to robot actions. This keeps track of robot stages/position to prevent mechanism collisions and/or illegal mechanism motions.
  - Driver chooses different control states for autonomous or human control.
- **Mechanism Control**
  - Elevator and Intake + Pivot use Kg/Kv feedfoward closed loop
  - Shooter uses a Velocity feedforward constant mapped from the minimum max range of Talon Fx Velocities
- **Driving**
  - Field-Oriented Drive with heavy odometry (motor encoders & gryo heading)
  - Discrete Kinematics fights drivetrain skew commonly incurred with swerve drive
  - Swerve Drive Motors use FOC and PIDF
- **Odometry & Shooter Automation**
  - Two Limelight 3s and one Limelight 2 are combined and cleaned with a Kalman filter to update Odometry
  - Limelight camera latency is accounted for
  - Turret + Mounting and Shooter + Pivot mechanisms use robot coordinates to accurately shoot