BREAKDOWN

254

2023

Technical Binder

Foreword

This Technical Binder details the game analysis, decisions, outcomes, and technical designs that guided us to our final robot for the 2023 FRC Season: *Charged Up.*

Our season started with game analysis, which helped the team determine the optimal strategies and robot requirements. With these requirements, subsystems were prototyped, designed, and built. With software unlocking the capabilities of this machine, we are ready for competition.

Team 254 is proud to present our 2023 robot: **BREAKDOWN**

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GAME ANALYSIS

Charged Up focuses on two complex challenges: scoring uniquely shaped cones and cubes and balancing on the Charge Station. To achieve our goal of winning Regionals and the World Championships, we need to do the following:

Qualifications

- Obtain as many ranking points as possible
- Ranking highly allows us the flexibility to form the type of alliance we want for playoffs

Playoffs

- Maximize our alliance's score to win all matches

These goals are aligned in that a strategy focused purely on scoring points will also gain ranking points, but there are slight differences between qualifications and playoffs.

Obtaining Ranking Points

- Ranking points are awarded as follows: two for winning a qual match, one for 5 links scored, and one for obtaining 26 alliance charge station points.
- To maximize ranking points in qualification matches, we must do the following:
  - Ensure alliance balances on Charge Station in Auto to get closer to Charge Sation RP
    - Goal: Preload + 1-object + Balance
  - Score 3-4 Links by ourselves to guarantee RP to make it easier to score RP with a randomized alliance
  - Mount the charge station in such a way that partners have sufficient space to balance with us

Winning Matches In Playoffs

- To maximize points, we must do the following:
  - Maximizing scoring in auton
    - Goal: Preload+2-object autonomous
    - 3rd robot balances on charge station
  - Minimize cycle time for scoring game pieces
    - Always be on the move to acquire game objects
    - Intake game objects the moment the robot touches it
    - Align quickly and swiftly score
  - Overcome defense
    - Be fast and maneuverable to avoid defenders. You don't need to fight through a defender who can't catch you.
    - Quickly go over cable-protector or Charge Station to have many options out of our scoring area

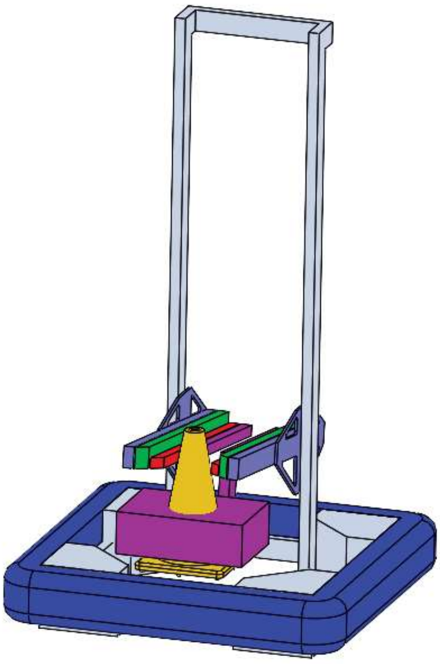
SUBSYSTEM STRATEGY

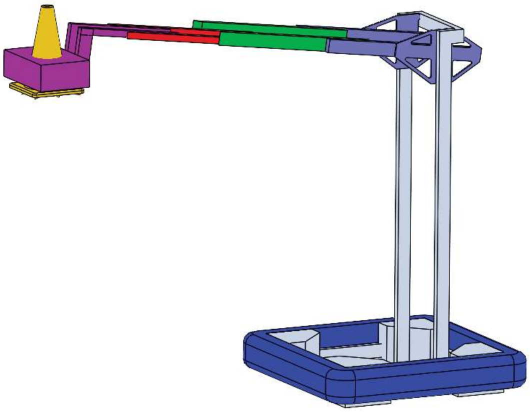
Drivebase

- Fast, light, low CG robot to drive fast, minimize cycle times, and prevent tipping

Intake and Scoring

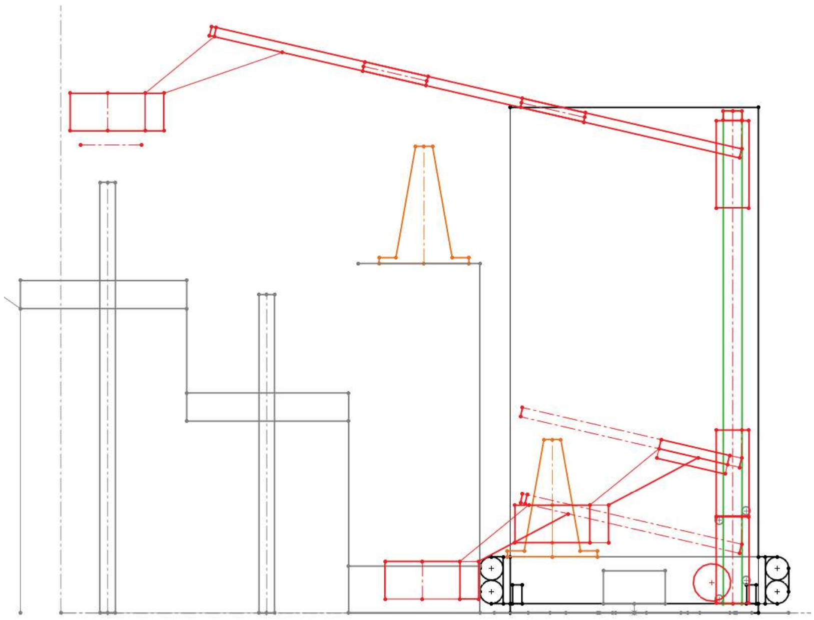
- Pickup both cones and cubes to enable solo-scoring Links
- "Touch it, own it" - be able to bounce off wall of substation, never slow down
- Obtain game objects from the ground and the substations
- Tradeoff/compromise: do not pursue acquiring sideways cones on ground, mechanically difficult and strategically unnecessary (at high levels of play, cones won't be loose on the ground)
- Maximize speed and robustness (keep up with intaking hundreds of objects during competition)

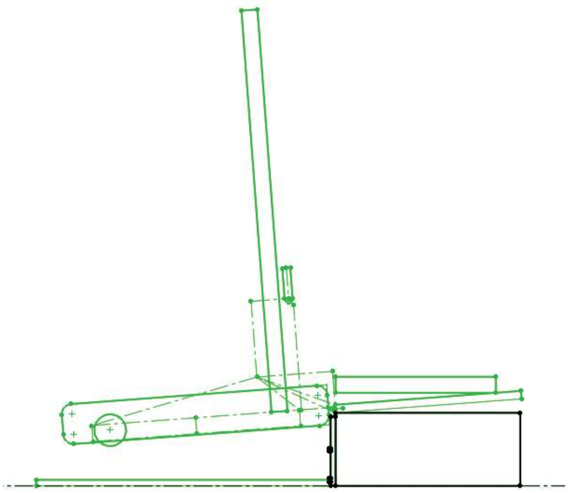




Climb

- Enable climbing last so we can do one more cycle

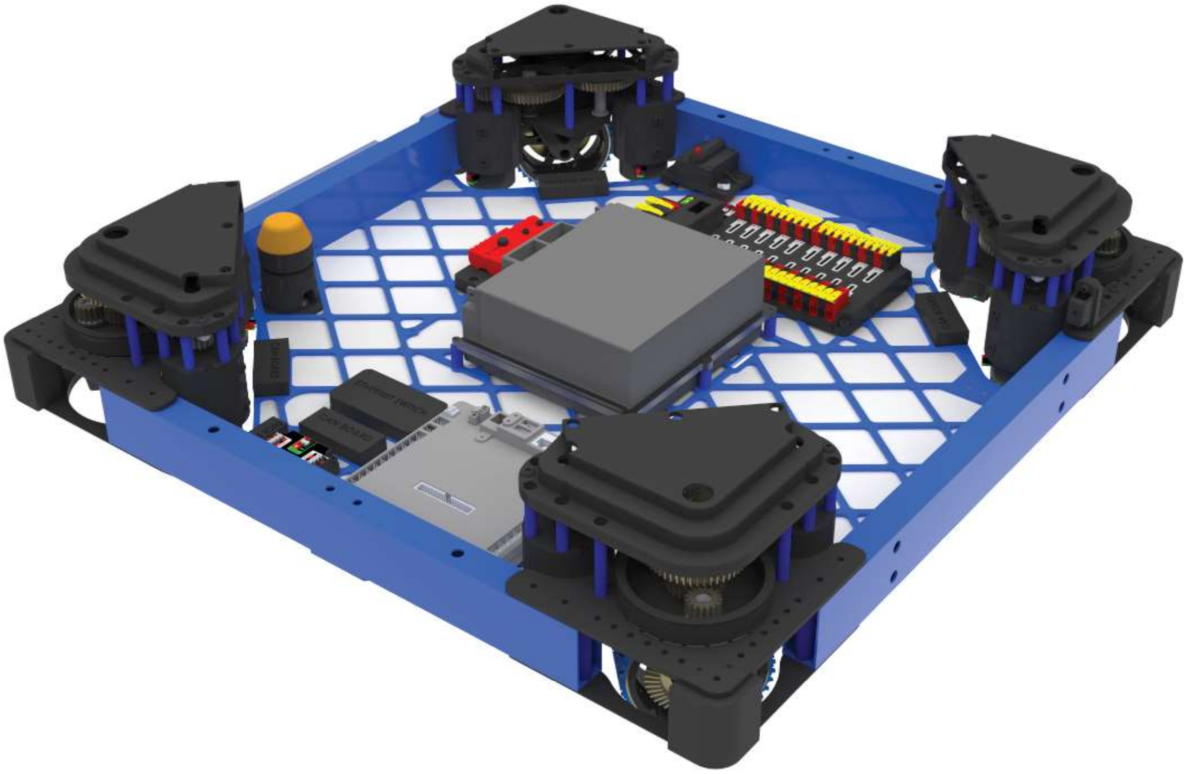




BREAKDOWN

Elevator
Laterator
Roller Claw Intake
Forks
Floor Intake
Drivebase
254
254
NASA
BOEING
Abbott
Greg and Gloria Shean

DRIVEBASE



The Drivebase allows the robot to maneuver around the field quickly and precisely. The swerve was chosen for its increased maneuverability and ability to avoid defense.

SDS MK4i Modules

- L3 drive reduction (18 ft/s) with 4" black nitrile treaded wheels
- Falcon 500s for drive and steering
- Customized with additional bearings to support falcon shafts

Chassis

- 26" x 26" frame
- 1/8" bellypan pocketed
- 2 Steel bellypans (15.5 lbs each) added to lower CG, increase stability

Electronics

- Battery in middle to centralize CG
- REV Power Hub

ELEVATOR

The Elevator controls the vertical movement of the Laterator and Forks. This allows for swift scoring at all levels of the Grid.

Elevator

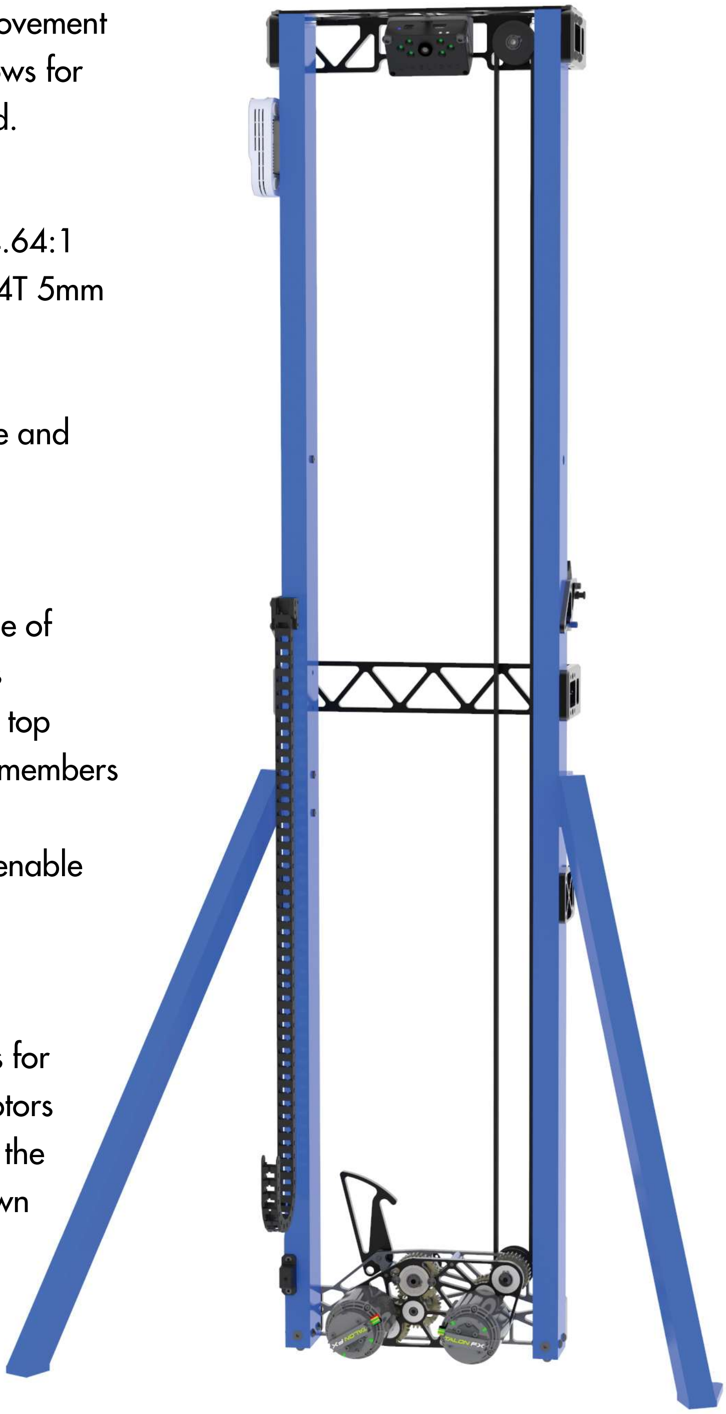
- 1 Falcon 500 drives 4.64:1 gearbox that drives 24T 5mm HTD pulley
- 2 x 1 x 1/16" Uprights supported by A-Frame and crossbars

Carriage

- Moves full 41.5" range of motion in 0.4 seconds
- 3/16" sideplates with top plate and side tensile members to increase stiffness
- Igus chain on side to enable smooth wire motion

Electronics

- Two hall effect sensors for Forks and Elevator motors
- Limelight at the top of the Elevator tilted 40° down



LATERATOR

The lateral elevator quickly moves the Roller Claw to a commanded position. A 3-stage, belt-driven cascading elevator tilted up 15° provides sufficient reach and height to score the furthest game objects.

Structure

- 1″ x 1″ carbon fiber tubes & plates for high stiffness and low weight
- 3D-printed belt clamps and pulleys for cascade rigging
- PEEK rollers on dowel pins enable low rolling friction at less weight than traditional steel bearings

Gearbox

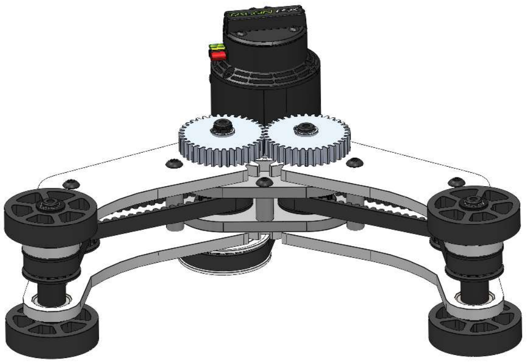
- 1 Falcon 500 powers 3.75:1 gearbox to 18T 5mm HTD pulley
- Covers 49.875″ total range of motion in 0.18s

Wire Management & Electronics

- Igus energy chains route wires around pulleys
- Hall effect sensor on Elevator Carriage zeroes motor encoder

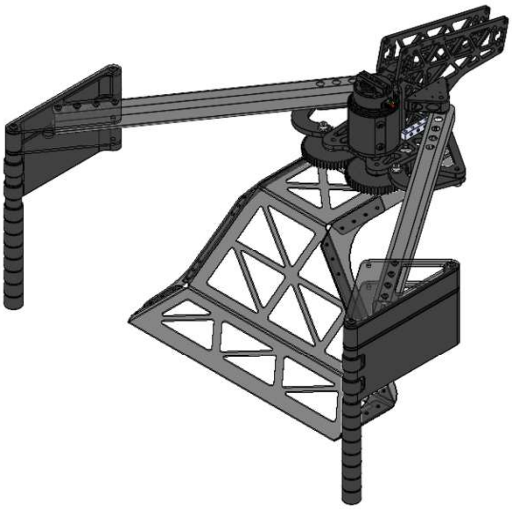
INTAKE PROTOTYPING

The hardest challenge was game-piece acquisition. Numerous intakes were prototyped throughout the season and are highlighted below:

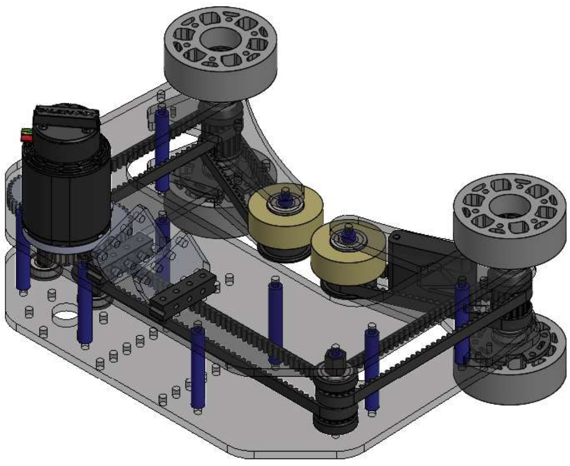


2-Roller Claw

2-Roller Floor Intake



Pinchy Claw



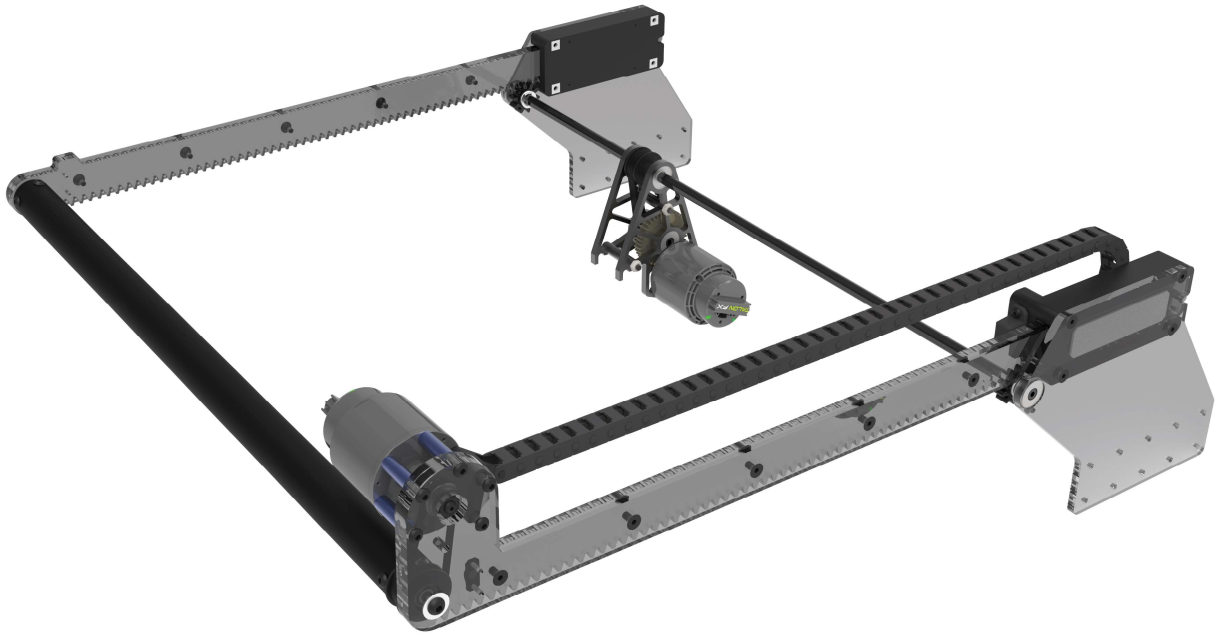
Articulating Roller Claw

ROLLER CLAW INTAKE

The articulating roller claw has wheels for both the cube and cone and, combined with the Floor Intake, enables the acquisition of upright cones and any cubes.

- 3″ flex wheels ½″ tall for centering game pieces and holding cubes
- 2″ Fairlane roller ½″ tall for gripping cones
- Articulating arms flip back to make space for cube or over-center to grip cone at 3 points
- Mounted 16° downward but cone hardstops tilted backward for scoring
- 1 Falcon 500 with a 1:3.5 reduction gearbox powers wheels via 18T pulleys and 5mm HTD belts
- Retroreflective sensor triggers when game object acquired

FLOOR INTAKE



The Floor Intake's grippy top roller pulls in cubes to the Roller Claw. Linearly deploysing with a rack-and-pinion directly driving the polycarbonate plates, it is robust but light.

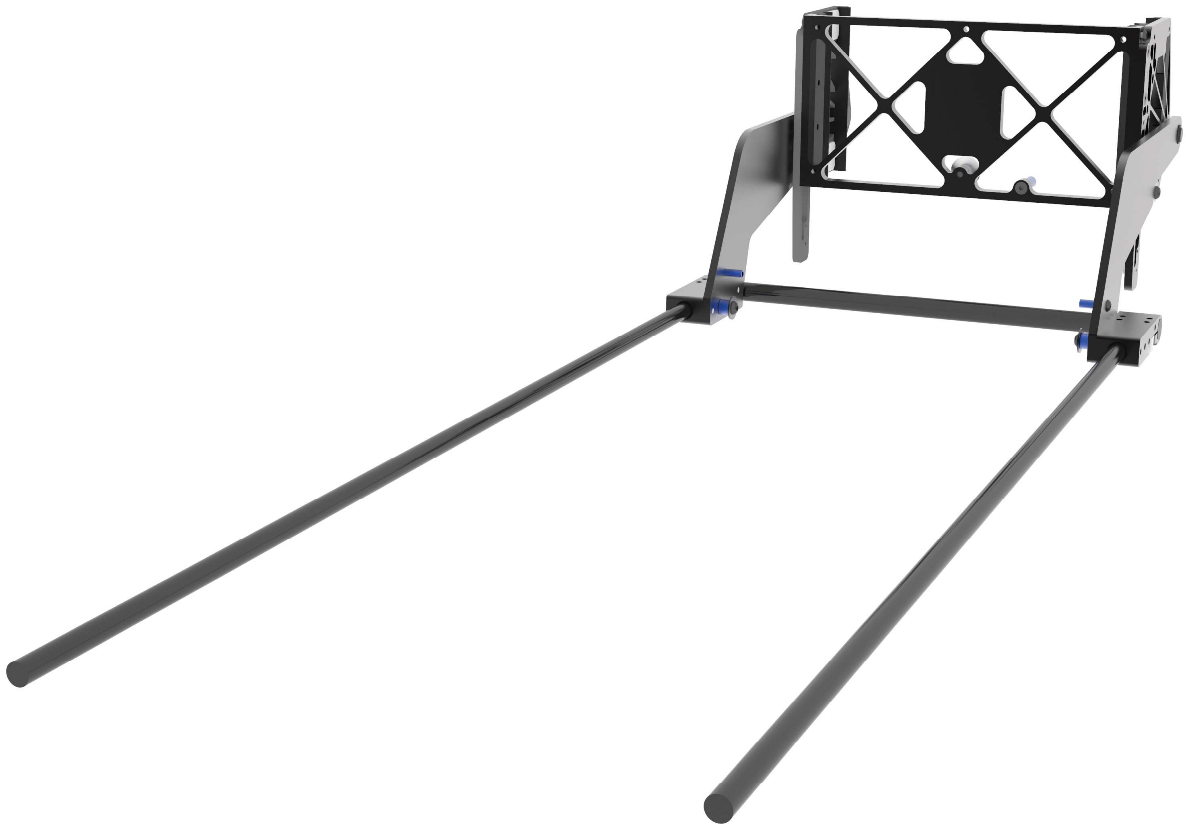
Roller

- 1.25″ OD 1/8″ wall polycarbonate tube with grippy material
- Dead-axle pulleys eliminates need for stand-offs
- 12T:18T HTD 5mm belt from Falcon 500 to roller

Extension

- 1 Falcon 500 powers 3.3:1 gearbox then 18T:18T pulley
- Outputs to 3/8″ hex jackshaft driving 10T 10DP pinions
- 10DP rack milled into one of 2 stacked ¼″ polycarbonate plates
- Igus energy chain cleanly routes wires

FORKS



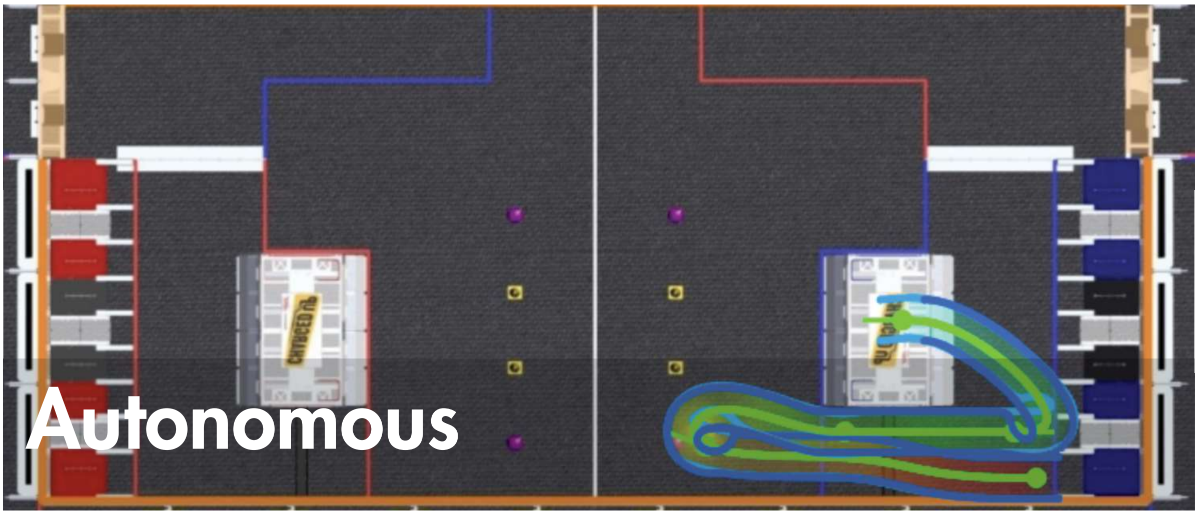
Carbon fiber forks pivot down, go under partners, and enable the robot to lift itself off the ground on the side of the bridge, enabling quick balancing.

Structure

- ½″ carbon fiber rods held by billet blocks on pivoting sideplates
- Carriage slides on Elevator uprights with teflon surfaces
- Sideplates press on Bumper wood to pivot robot up, counteracting sag

Gearbox

- 1 Falcon 500 powers 14.6:1 gearbox that outputs to 1″ OD drum to pull dyneema and move 6.75″ travel in 1s
- Surgical tubing pulls Fork Carriage up to deploy and enable pivot-down



Autonomous

The robot smoothly follows precalculated trajectories autonomously through the use of both feedforward control based on precomputed robot velocities and feedback control on position error.

Path Generation

- Generated using parametric quintic hermite splines and a web-based visualizer
- Optimized to minimize the change in curvature over multiple splines to limit large torques that could result in wheel slip and inaccuracy.
- Results in smoother paths that allow for more reliable tracking

Driving Controller

- Uses a Pure Pursuit controller to follow generated trajectories and P controllers for translational and rotational errors
- Generates setpoints for individual swerve modules based on physical module constraints, preventing modules from fighting each other and improving odometry

Tele-op

Each subsystem is controlled through a state machine, managed by an overall superstructure state machine to coordinate individual subsystem actions.

Superstructure Movement

- Generates intermediate states for the Elevator and Laterator to avoid potential collisions based on the current goal state and previous goal state
- Transitions between intermediate states faster when less precision is needed, optimizing superstructure movement and decreasing the time necessary to reach the desired goal state
- The Laterator enters a “springy” mode when intaking from the Substation reducing the impact of collisions

Driving

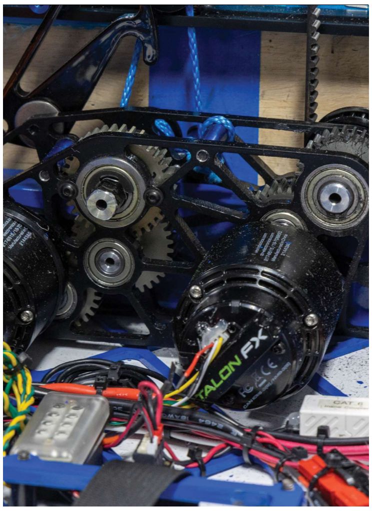
- Standard field-centric control of a swerve drive that uses odometry (gyro and wheel encoders) and vision to estimate position
- Velocity and acceleration constraints on the Drivebase prevents wheel slip, providing more controlled movements
- Heading controller maintains robot direction while driving and snaps to desired directions
- Computes desired position and works backward to determine individual module desired states, reducing skew while simultaneously rotating and translating

Localization

A Limelight 3 camera provides the robot's location relative to the nearest April Tag to estimate the robot's position in conjunction with odometry.

Pose Estimation

- Uses a Kalman filter to fuse vision updates with odometry for estimating position
- In tele-op, the robot uses the pinhole camera model to project the corners of the April Tag onto the camera's xz plane to find distance to the Twag
- When disabled, the robot uses OpenCV's SolvePnP to find the robot's location relative to the field


TALON FX