



# REEFSCAPE

- 
- 6995 Team NOMAD

## Technical Binder 2025

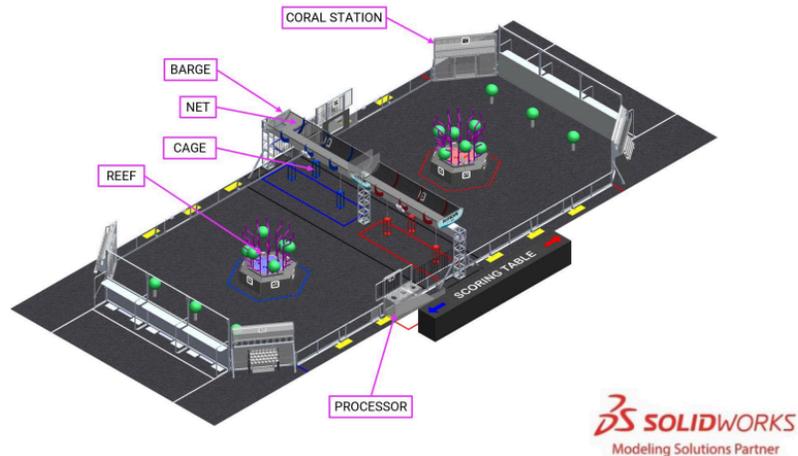


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# ANALYSIS

## REEFSCAPE



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REEFSCAPE presents three main challenges: harvesting and scoring Algae into the Processor or Net, collecting and placing Coral onto the Reef, and climbing on a cage in the endgame. Alliances also earn additional rewards for meeting specific scoring thresholds and for cooperating with their opponents.

Stacks of Coral and Algae are laid out on the alliance side of the field before the game begins. During both autonomous and teleoperated periods, additional Coral can be given to the robot by a human player using either of the two stations, located next to the alliance walls. Additional Algae is located on the field in between the Reef branches.

Our team's goal is to be able to do all of the game tasks as quickly and as efficiently as possible at Regional competitions and Worlds. To do this we need to:

- Collect coral from the station quickly
- Harvest algae from in between the reef branches
- Score on all reef scoring areas (Levels 1, 2, 3, 4)
- Score algae in the processor and net
- Be able to scale the shallow or deep cages hanging from the barge

We'll explain our thought process in the following sections covering strategy and priority.

# ANALYSIS strategy

		MATCH points		Ranking Points	Coopertition Points
		AUTO	TELEOP		
<b>LEAVE</b>		3			
<b>CORAL</b>	CORAL scored in trough (L1)	3	2		
	CORAL scored on L2 BRANCH	4	3		
	CORAL scored on L3 BRANCH	6	4		
	CORAL scored on L4 BRANCH	7	5		
<b>ALGAE</b>	scored in PROCESSOR	6	6		
	scored in NET	4	4		
<b>BARGE</b>	PARK in the BARGE ZONE		2		
	off-the-ground via shallow CAGE		6		
	off-the-ground via deep CAGE		12		
<b>Coopertition Bonus</b> – at least 2 ALGAE scored in each PROCESSOR					1
<b>AUTO RP</b> - all non-BYPASSED ROBOTS LEAVE and at least 1 CORAL scored in AUTO				1	
<b>*CORAL RP</b> - If at least 5 CORAL scored on each level. If <i>Coopertition</i> achieved, at least 5 CORAL must be scored on each of 3 levels.				1	
<b>*BARGE RP</b> - at least 14 BARGE points are scored				1	
<b>Win</b>	completing a MATCH with more MATCH points than your opponent			3	
<b>Tie</b>	completing a MATCH with the same number of MATCH points as your opponent			1	
*For District Championship and/or <i>FIRST</i> Championship events, the CORAL or BARGE RP requirement may increase.					

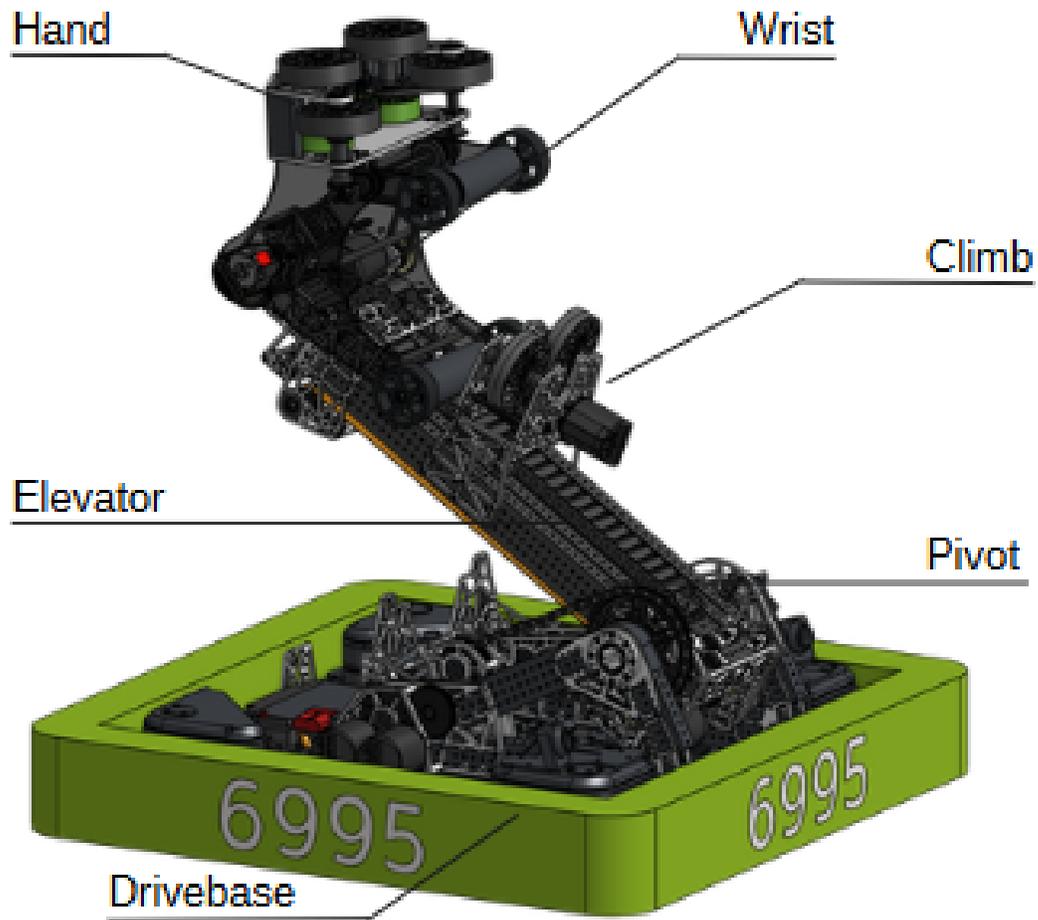
Coral stands out as the primary scoring objective in this year's game. Not only do they provide a nearly unlimited source of points (60 per Coral Station), but they also result in two of the main Ranking Points (Auto RP and Coral RP). While it seems worth it to also score all the Algae in the Processor (+6), because the processed Algae goes to the opposing Human Player to score in the opposing Net (-4), directly scoring in the Net provides a better Net point incentive to score there (+2 vs. +4). For cage climbing, Deep Climbing's ability to almost fill out all the points necessary for the Barge RP makes it an essential part of the game for maximum RP during qualification matches and lots of points during elimination matches.

# ANALYSIS priority list

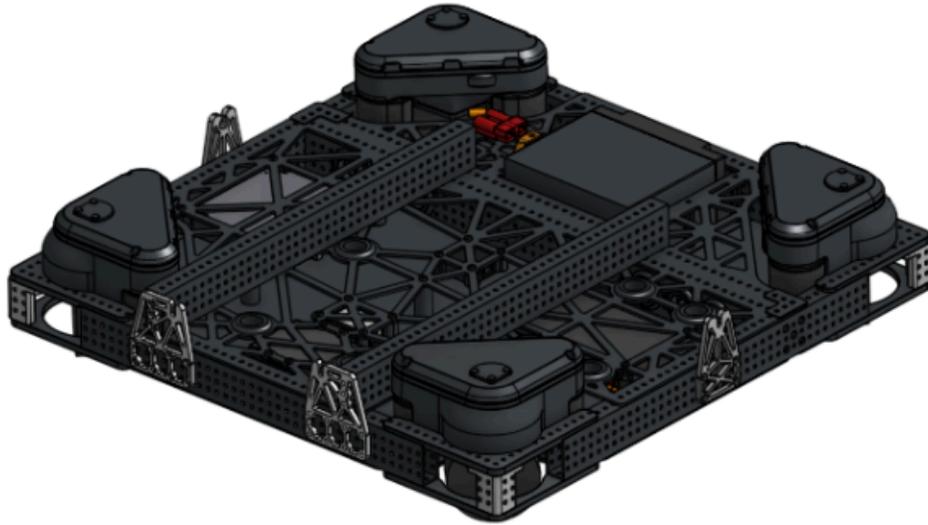
1. Drivebase
  - a. Small and robust
    - i. Under weight limit of 115 lbs
    - ii. Under drivebase perimeter limit of 120 in
  - b. Brainpan - Bellypan setup. Protected electronics
2. Pivot
  - a. Be able to control the elevator's pivot motion
  - b. Robust and speedy to be able to perform quick cycles
3. Elevator
  - a. Be able to extend up to the Net
  - b. Be able to extend up Level 4 Reef branches
  - c. Can hold both Hand and Climb
4. Hand
  - a. Be able to score both Coral and Algae with the same mechanism
  - b. Be able to intake Coral from the Coral Station
  - c. Robust ability to score Coral on Levels 1 - 4
  - d. Be able to harvest Algae off the Reef
  - e. Be able to score Algae in the Net and the Processor
5. Climb
  - a. Hang every match in under 5 seconds
  - b. Stay up for more than 3 seconds
  - c. Simple, light design
  - d. Deep Cage ability > Shallow Cage ability

We elected to prioritize the Deep Cage climb ability over the Shallow Cage climb ability. We knew that if we neglected to make our robot design around the Deep Cage climb, we would struggle with the later implementation of the mechanism. Additionally, there are no real benefits to climbing Shallow Cages with the ability to Climb Deep Cages. Deep Cages are worth more points, have the potential to be faster, and can make Barge RP scoring easier. As a result, our design does not include the Shallow Climb as a main ability.

# DESIGN



# Drivebase



## Goals:

- Simple, agile, fast drivebase with swerve to increase maneuverability
- Protective electronics setup
- Fast and simple bumper attachment

## Chassis:

- 28.5" by 28.5" frame
- 2" x 1" x 3/32" black-anodized aluminum tubes

## Swerve:

- Swerve Drive Specialties MK4i modules with modified L1 gearing for acceleration and counter-defense
- 4" Grip Lock wheels with 3d printed inserts for strengthening
- Custom 3D printed covers to keep dust and grime from getting into modules.
- CTRE Kraken X60 motors for potential 13.6 ft/s free speed



## Brainpan:

- Brainpan design - all important electronics are flipped upside down.
- 1/8" Pocketed aluminum brainpan plate
- Rubber wiring grommets in brainpan to prevent sharp edges from slicing wires
- Allows for more top space to mount subsystems.
- Two crosstubes on top for Pivot mounting

## Bellypan:

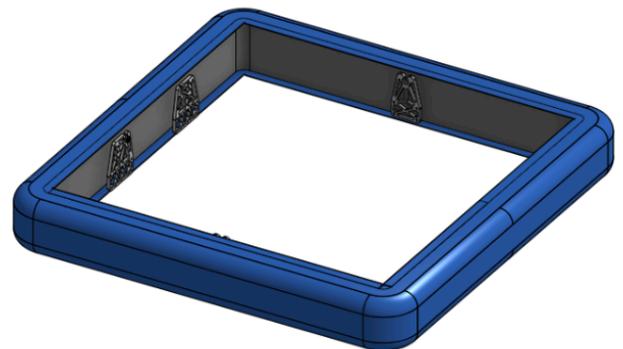
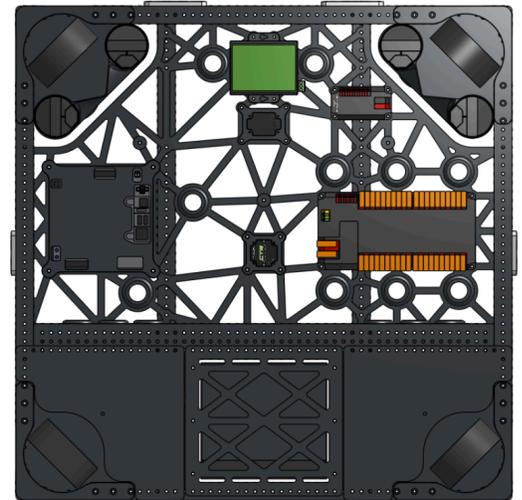
- 1/16" dark-tinted polycarbonate sheet under robot
- Protects electronics & wiring

## Electronics:

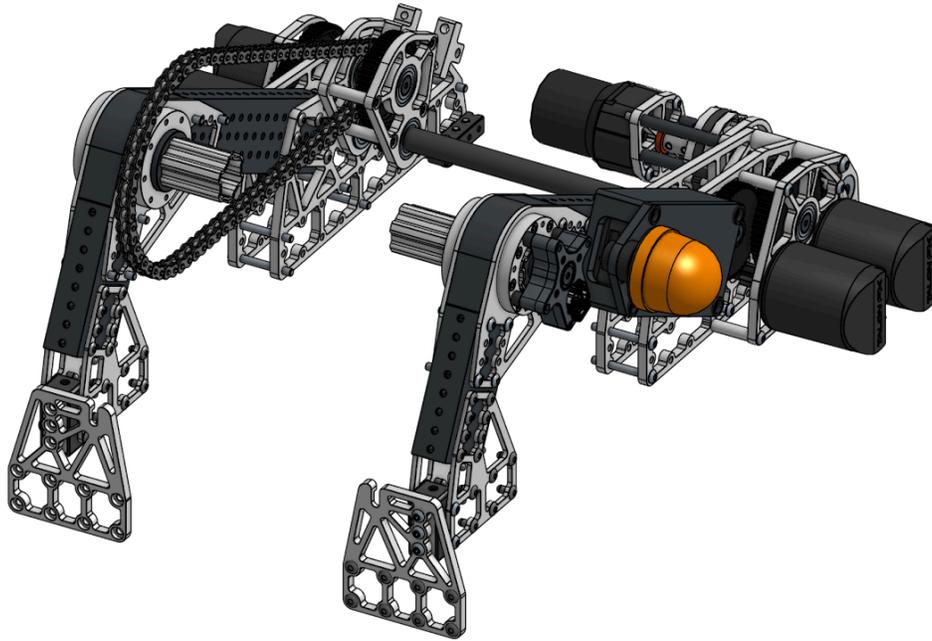
- Battery opposite to Pivot to balance CG
- REV Power Distribution Hub
  - 40A breakers for all 18 motors
- CTRE Pigeon 2.0 for heading feedback

## Bumpers:

- One piece overlap style bumpers
- Aluminum mounting plates attached to frame that allow bumper attachment
- Simple bolt-nut mounting



# Pivot



## Goals:

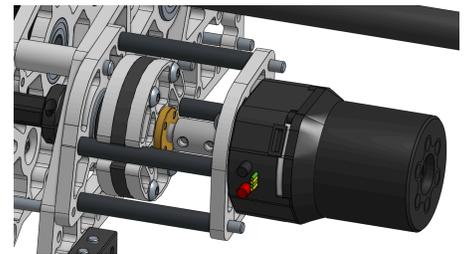
- Be able to lift our Elevator, Climb and Hand assemblies
- Maintain low center of gravity
- Robust, high-torque mechanism that can accurately move to different orientations
- Reach desired end-position in 0.25 seconds

## Friction-Brake:

- Custom rubber friction-brake
  - Prevents Elevator from falling while disabled or scoring
  - Lead screw driven by a single NEO Vortex
  - Free-spinning motor allows for easy human interaction

## Gearbox:

- 123.45:1 gear ratio on pivot
- Four Kraken X60s with Motion Magic
- All gears shimmed and clocked to eliminate backlash

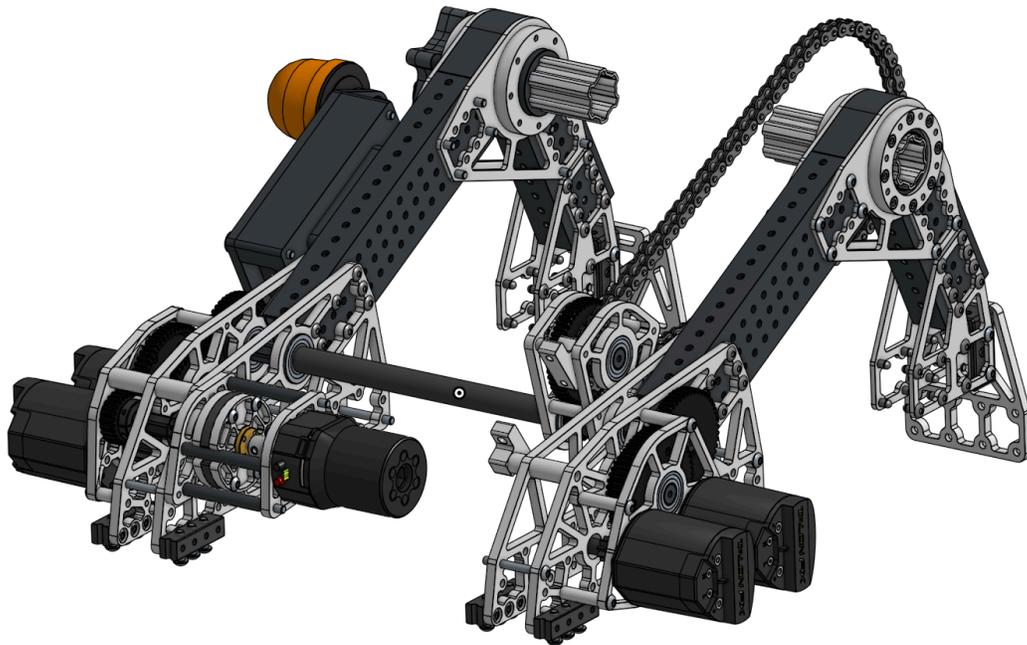
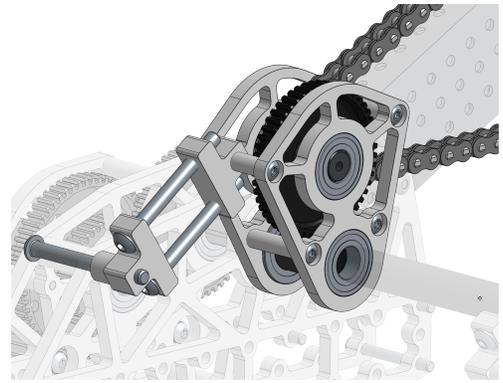


## Pivot:

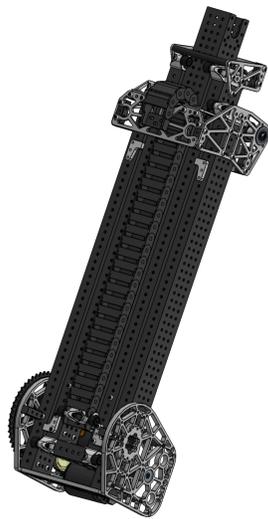
- MAXSpline stub axles hold Elevator sprockets
- Absolute CANCoder 1:1 with pivot, off-axis
- Tensioner to eliminate backlash and slop from system

## Structure:

- 16.8 lbs
- 1/8" mounting plates to frame tubes and crosstubes
- Bolts into crosstubes, frame, and brainpan



# Elevator



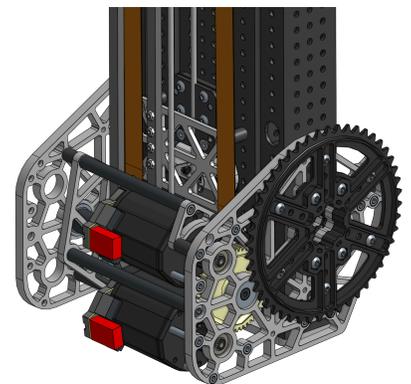
Our elevator this year was largely based on our 2023 robot's elevator for Charged Up, with the difference being the main pivoting element of the arm was closer to one end of the arm, rather than the middle of the elevator.

## Goals:

- Be able to lift our Hand and support Climb
- Be able to reach both L4 and the Barge at max extension
- Accurate elevator that can extend/retract to different scoring heights
- Fast extension (<0.25s)
- Light and durable
- Maintains low CG

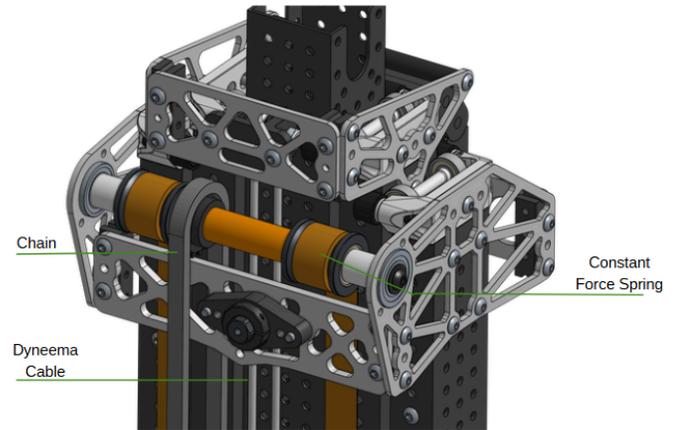
## Gearbox:

- Two Kraken X60s
  - Pinions drive larger gear with a pulley on the same axle that powers the belt
  - Belt movement is bound to the first extending stage by trapping it between two plates.



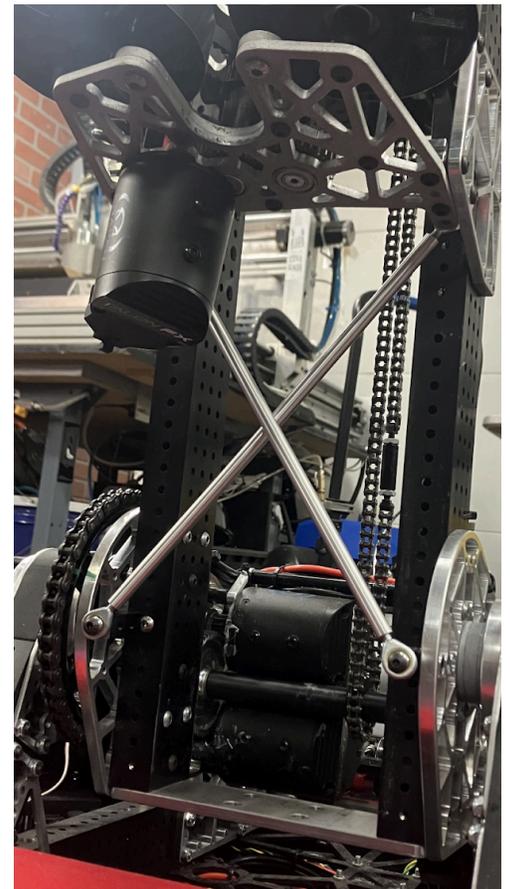
## Power Transmission:

- Chain
  - Simple and able to withstand the load of extending the elevator
  - Prevents skipping like a belt might because of strong acceleration
- Constant Force Spring
  - Makes extension faster and takes some load off the motors.
- Dyneema Cable
  - Ultra-light polyethylene fibers that are 15x stronger than steel
  - Low-stretch, perfect for elevator rigging
- SDS bearing blocks
  - Chosen for smooth extension/retraction

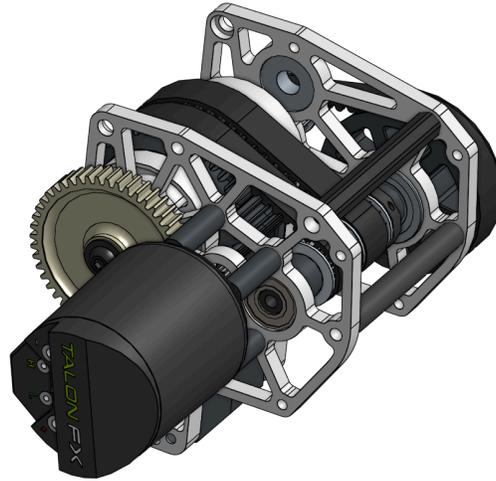


## Structure:

- 17.9 lb 2-stage cascade elevator with each stage extension 20 in.
  - To score in L4/Net the Hand reaches the rest of the distance
  - 2"x2" center tube and 4x 2"x1" tubes.
- REV Anodized Billet Sprockets that connect to Pivot chain
- SDS Elevator Bearing Blocks act as corner tube plugs
- Cable Chain that holds wires connects to top plates of the base tubes.
- Main Elevator Plates that hold MAXSpline stubs and Sprocket are 0.3125"
- Top Elevator Plates are 0.125"
- Dedicated cable routes/holes in CAD made sure wiring in the cascade is solid.
- Climb mechanism and crossed tie rods keep base stage rigid.



# Wrist



## Goals:

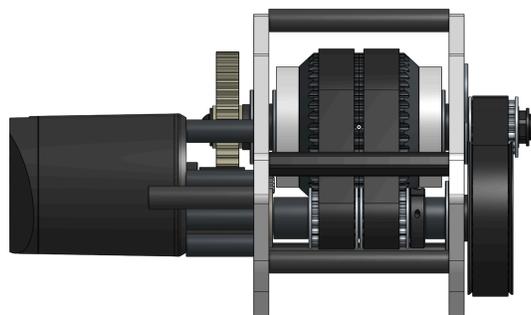
- Allow for versatile angular movement of the hand
- Light design for robust, fast pivot

## Gearbox:

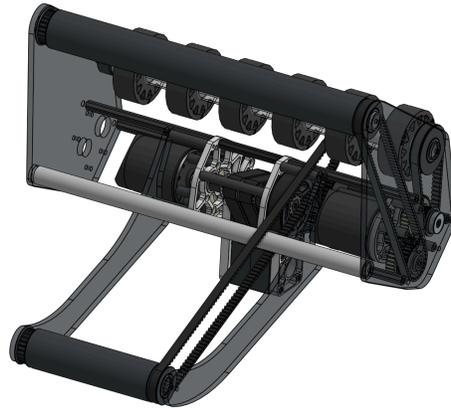
- 38:1 Gear Ratio
- 1 Kraken X60 drives pinions
- Custom 3D-Print Pulley Inserts that sit in the center elevator tube

## Structure:

- Two main aluminum 1/4" plates
  - Held together by spacers and bolts
- 3.4 lbs assembly



# Hand 1.0 (Station)



## Goals:

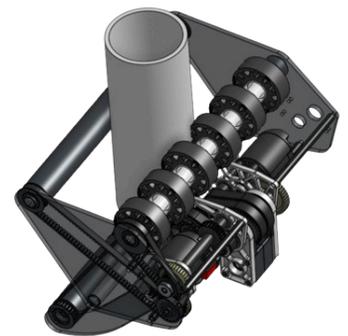
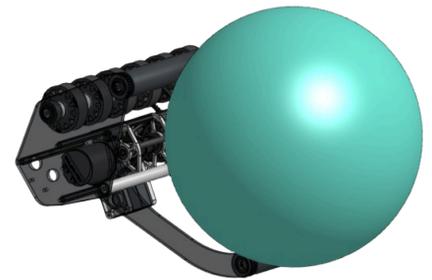
- Quickly grab game pieces
  - Both coral and algae
- Durable, lightweight, simplistic
  - Getting side-swiped does not ruin the hand

## Rollers:

- Uses a single motor to drive belts and gears.
  - Direction needed to rotate depends on whether we are intaking/ejecting coral or algae.
- 1 coral roller with 6 x 3" compliant wheels
  - Custom 3D-printed Pulleys
  - Used for Coral with one of the silicone rollers
  - Wheels spaced 1.5" apart
- 2 x 1.625" rollers
  - Custom 3D-Printed Pulleys
  - Used for Algae
  - 1 is grip tape, 1 is silicone

## Structure:

- Two main polycarbonate plates for the main structure
  - Two Plates for the additional roller for the Algae
- 5.975 lbs hand; 9.375 total Wrist + Hand
- 1 Kraken X60 powers all rollers using gears and belts.



# Hand 2.0 (Ground)



We wished to keep most of the base functionality of our hand, so our wrist remained unchanged, and we still wanted a design that could use one motor to drive all the rollers to save weight and reduce motor count.

## Goals:

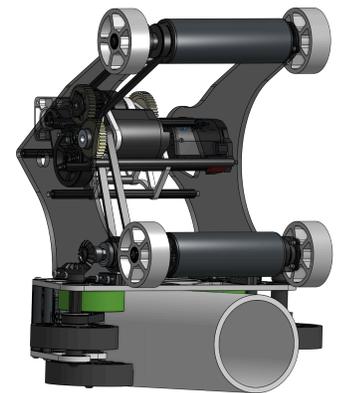
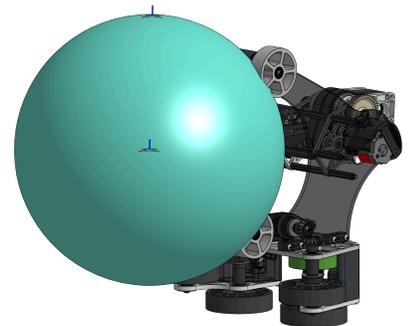
- Ground intake of coral
  - We realized ground coral intake was much more important than previously anticipated
- Quickly grab both game pieces
  - Touch it-own it reliability
- Durable, lightweight, simplistic
  - Getting side-swiped does not ruin the hand

## Power Transmission:

- 2 x 1.5" Rollers, with 2" compliant wheels on the edges to pick up algae.
- 6 vertical wheels (2 outside, 4 inside) that can intake coral from the ground and station
- Algae roller helps keep ground coral contained when intaking.
- Bevel gears take motion transfer from rollers to wheels.

## Structure:

- 2 main polycarbonate plates hold horizontal rollers and main structure
- 1 Aluminum half-pocketed plate holds vertical wheels and the horizontal structure.
- Carefully thought out algae rollers vs. coral rollers to give them different ratios.



# Climb 1.0 (Hook)



## Goals:

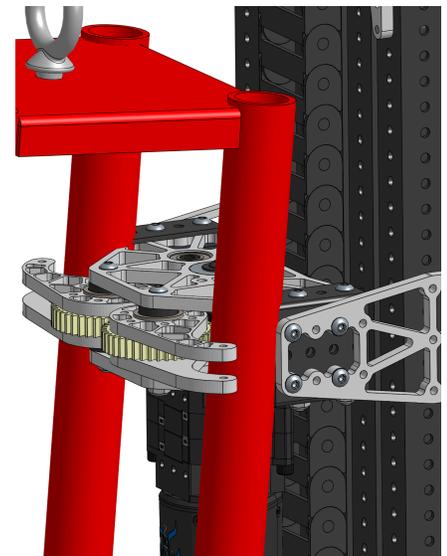
- Super simple inward hook climb
- Quickly grab cage and start climbing in <5s
- Light, robust, able to lift 120 lbs over the hooks

## Gearbox:

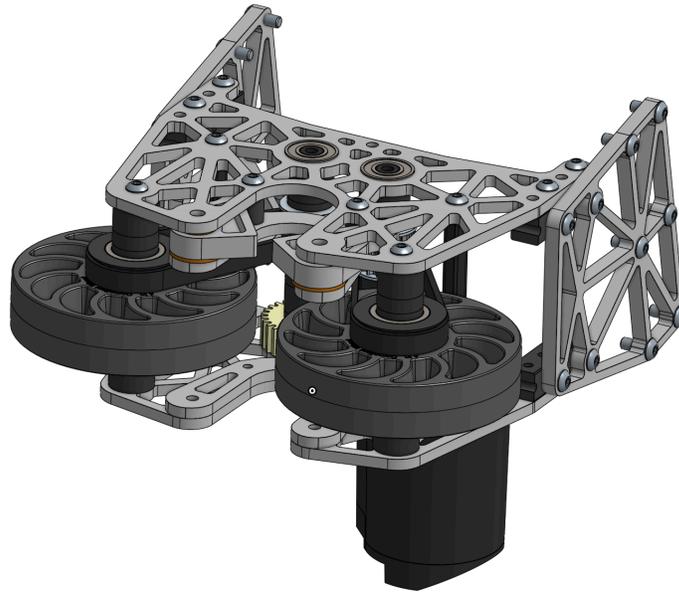
- 196.875:1 reduction
  - 2 5:1, 1 3:1 MAXPlanetary stages driven by Kraken X60
- Single stage of gearings

## Structure:

- 1/4" pocketed aluminum plates attach to the side of the Elevator
- 0.09" wall C-Channel that holds main Climb plates
  - 1/4" main Climb plates
- 4x 1/4" Climb Hooks
  - Connected through tapped gears on 3/8" shafts
- Grip Tape custom 3D Print blocks that go in between the the main plates



# Climb 2.0 (Latch)



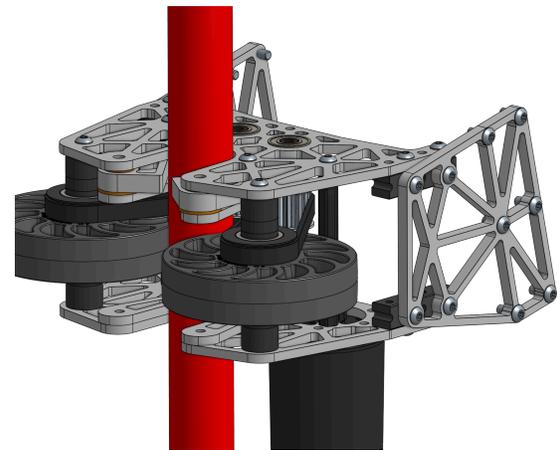
After our 3 regionals, we decided to change our climb because it wasn't consistent enough to always hold the required 3 seconds to get the climb points. Thus, we have swapped to a wheel-latch climb for better grip and pull on the cage.

## Goals:

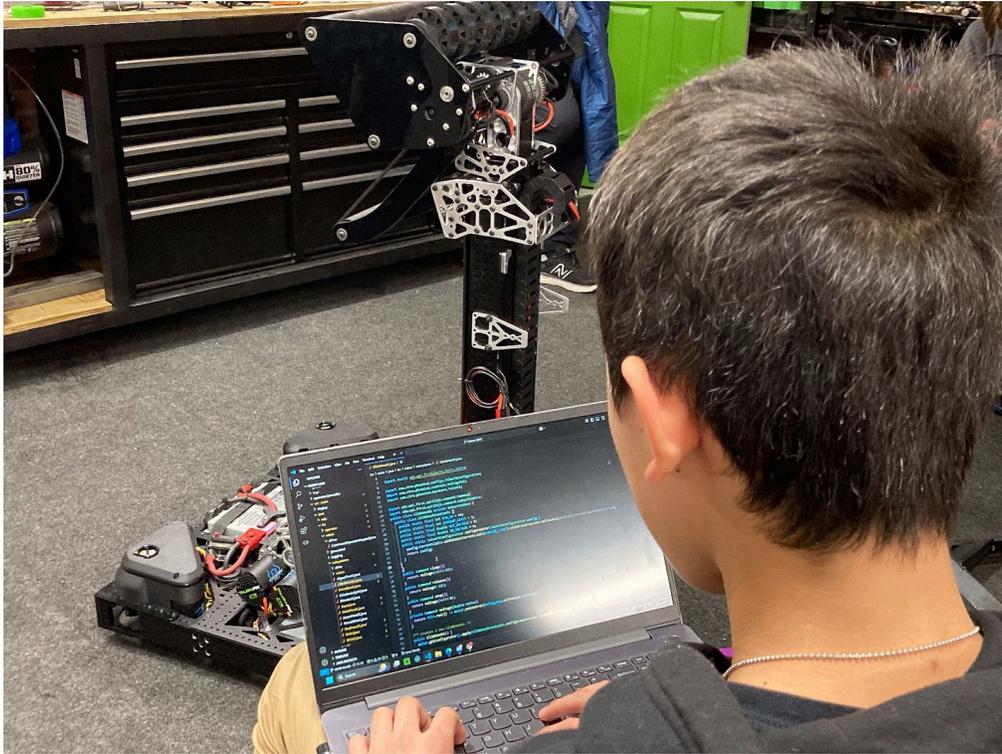
- Wheel-based Latch climb.
- Grabs a single cage bar, climbs in <5s, is reliable to stay up after the 3s disable after the match.
- Light, robust, able to lift 120 lbs over the hooks

## Structure:

- 1/4" pocketed aluminum plates attach to the side of the Elevator. 12 degree tilt gives extra climb height.
- 4 Aluminum Nutstrips hold together the Climb Assembly
  - 1/4" main Climb plates (2 on top, 1 grabbing bottom, both pocketed)
- 2x 4" diameter MAXSpline wheels
  - Connected through tapped gears on 3/8" shafts
- 2 Latches, half pocketed, motion stopped by spacers.
- 14t Pinion drives both wheel assemblies (28t gears symmetrical)



# Programming

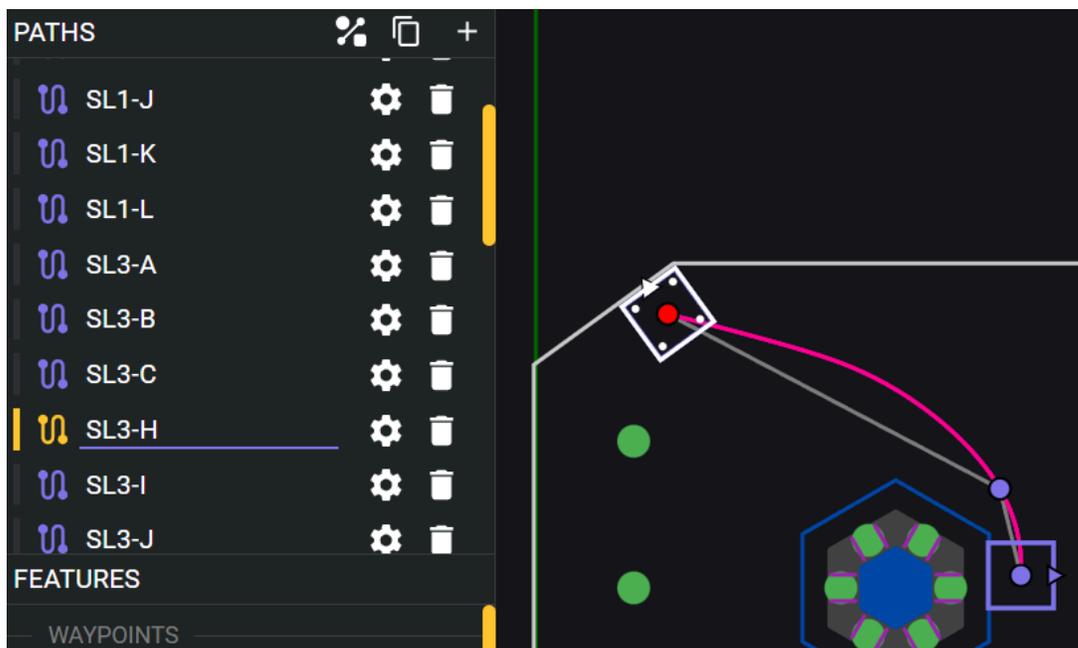


- General
- Autonomous
- Drivebase
- Arm (Pivot, Elevator, Wrist)
- Hand
- Climb
- Vision
- Driver Control

# General

- Coded in WPILib Java
  - Public Github: frc6995/Robot-2025
- All position subsystems have soft limits that prevent overextension
- Subsystems were imported into AdvantageScope to visualize robot
  - Allows viewing logged data
  - Allows testing robot code virtually

# Autonomous



- We have a large number of different auto paths to maximize our alliance capability and accommodate our alliance partners, including 3p side auto, 2.5p driver-station-side, and 1p coral 2p algae net-side.
- We use 4 cameras to detect AprilTags which help our robot adjust its path and align to locations on the reef.
- We ensure that our auto runs consistently using a combination of path following and auto-align, while avoiding inconsistency caused by extending the arm while moving.

- This year we have implemented a new system for creating auto paths that utilizes a modular structure, combining many premade small paths between key locations, allowing us to easily and efficiently create new autonomous routines.

## Drivebase

- Our robot has four swerve modules: one on each corner of the drivebase. Each module is equipped with two motors. One motor spins the wheel for driving and the other turns it for steering. Unlike tank drive, which we used in the past, our drivebase can move in any direction at any angle, allowing for significant driver control and freedom.
- We ensure that the default command in autonomous is a stop, instead of following the joysticks.
  - Otherwise, if the joystick is not centered at the start of the auto, it keeps that value during autonomous, causing undesired motion.
  - We use PID and feed-forward constants to keep our drivebase running as smoothly as possible.
- Absolute encoder on each motor to measure the heading of the wheel on startup.
- Drivebase utilizes the CTRE Pigeon gyroscope, CANivore and 8x Kraken X60s.
- Primary challenge is tuning the control loops for module speed and angle, and the feedback loops that calculate desired drivetrain speed based on distance from a target position.
- We are able to easily calculate the speed and rotation of our drivebase, so we can constantly update the robot's position on the field.
- The robot knows where it is at all times and uses AprilTags around the field to correct any errors caused by skidding or deflection, allowing us to accurately and automatically align the robot to areas on the coral stations or any position on the reef.

# Arm (Pivot, Elevator, Wrist)

## General Overview

- Our Arm is programmed in a Position based system, using motion profiling to drive each subsystem to a target position containing values for pivot angle, elevator extension, and wrist angle.
  - Motion profiling - a method using pre-set values for acceleration and velocity to allow smooth and precise movement to a given position
  - Each motor uses Phoenix 6 Motion Magic profiling to ensure limited acceleration, velocity, and current draw throughout the movement.
- Nearly all arm motion uses the same sequence of intermediate states.
  - This command is a sequence of: (1) retracting the elevator (2) pivoting to the new angle (3) extending the elevator.
  - Additional restrictions on wrist and elevator movement keep the hand from hitting the drivetrain or elevator mechanism.

## Pivot

- Driven by four CTRE Kraken X60 motors; 1 lead and 3 followers, copying the leader
  - Inversion applied as necessary based on the pivot's gearing.
- Exact pivot angle determined by off-axis absolute encoder
- Pivot is driven to target positions by a motion profile
- Soft limits prevent hardware damage even if arm motion goes outside normal range.
  - If the pivot is at the limit, the motors will not be allowed to drive the pivot any further in that direction
- The amount of voltage on the pivot motors that is needed in order to counteract the force of gravity varies depending on several factors, including angle of pivot, extension length of elevator, and whether or not we are holding a game piece.
- Friction-brake locking mechanism secures arm in place against gravity.
  - Added primarily to help stop the elevator from falling. Without the rubber pad applying friction, the elevator would fall if more than 10 degrees from vertical.
  - Also added for the climb mechanism, after discovering the pivot motors themselves are unable to hold the robot in the climb position for 3 seconds.

## Elevator

- Driven by two CTRE Kraken X60 motors; 1 lead and 1 follower.

- Elevator extension is determined by a relative encoder, which is homed on startup with the assumption that the elevator will be at the minimum extension.
- The needed voltage for gravity compensation on the elevator motors varies depending on pivot angle.

### Wrist

- Driven by one CTRE Kraken X60 motor
- Pivot rotation is determined by a relative encoder, which is homed at the hard stop at one end of the wrist's rotation range.

## Hand

- Uses a motor to drive a system of rollers connected by belts and gears.
  - Direction needed to rotate depends on whether we are intaking or ejecting either a coral or an algae.
- The hand has limited speed for the rollers depending on the game piece we intake.
  - These speeds are tuned to pick up game pieces quickly without the danger of knocking them away or pushing algae against the backstop.
- We use a time-of-flight sensor to detect when we have a coral in our possession. When a game piece breaks the path of the beam, our arm and hand automatically retract to the “stowed” position.

## Climb

- One operator button starts spinning the wheels and moves the arm to a position to grab the cage.
- After the cage is locked in place, another button pivots the elevator down in order to pull the drivebase off the ground.
- Once the arm is at the desired climb angle, a third button engages the brake.

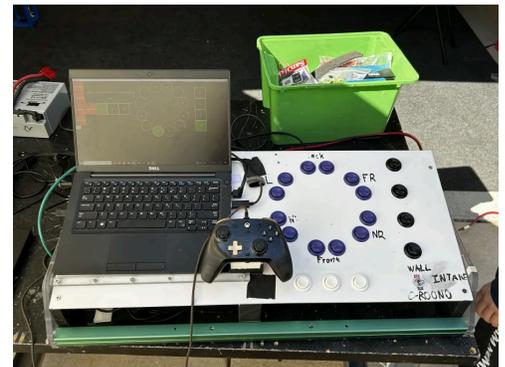
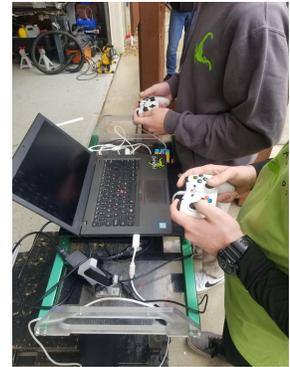
## Vision

- For vision, we have four cameras on the robot, positioned so that we can see the reef April Tags no matter which direction we are facing.
- We use two Orange Pi processors running PhotonVision, with each Pi running two cameras.

- AprilTags are visual markers detected by the cameras on our robot.
- The reference system provides robots with a spatial reference to calculate their position in three-dimensional space. This year, there are 22 tags around the field.
- Our robot knows how it has moved at all times by measuring wheel movement, but our reference point can be wrong because of defense/skidding
  - We use AprilTags to correct these errors and keep constant reference points.
- Our cameras analyze the images of the tags to determine the relative distance, yaw, pitch, and roll compared with the robot.
  - This gives our robot the information necessary to measure its position on the field precisely.

## Driver Control

- Our driver uses a standard Xbox controller, while our operator utilizes a custom-designed, manufactured, and programmed button board.
- Driver responsibilities:
  - Controlling the swerve drivebase
  - Intaking and scoring algae
  - Intaking and scoring coral
  - Auto aligning to targets (coral station/berge/processor/cage/reef)
- Operator responsibilities:
  - Plan the strategy for the scoring in advance
  - Use the Operator Board to pre-select which branch and level on the reef to score on
  - Operate climb sequence
- When the Operator uses the Operator Board to pre-select which branch and level on the reef to score on, it will illuminate a visual on the Driver Station Laptop.
  - When it's time to align, the driver holds down a button to auto-align to the pre-selected position, and score when the position is reached.
- We decided that a button board with a dedicated button for each position on the reef (along with additional operator functions) would be most effective.



- The button board allows the operator to visualize operations better and perform tasks more quickly and accurately.
- Level 3 and 4 coral scoring and reef algae removal can be done from both sides of the robot. The code automatically selects the side to use based on the direction the robot is facing.
- The robot has 6 options for scoring coral (L1-4 with the pivot away from the reef, and L3-4 with the pivot towards the reef).
  - Each option has its own auto-align positions, arm positions and extend-retract sequences, and desired hand voltage for scoring.
  - This allows us to optimize the robot's motion during and after each score.
- Our driver station features displays for both the driver and operator.
  - These displays include an auto selector, status feedback, a graphic of the operator's selected position, and other displays to help the driver control.

