UNDERTOW

254

2025 Technical Binder

Foreword

This Technical Binder details the game analysis, decisions, outcomes, and technical designs that guided us to our final robot for the 2025 FRC Season: Reefscape.

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 2025 robot: **UNDERTOW**

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GAME ANALYSIS

REEFSCAPE, presents various challenges: scoring Coral on the 4 levels of the Reef, scoring Algae in the Barge and Processor, and climbing a Cage during the Endgame. Team 254's goal is to win all our regionals and the World Championship. To achieve this, we need to do the following in each phase of the tournament:

Qualifications

- Maximize acquisition of ranking points
  - Seeding first allows us the flexibility to form the type of alliance we want for the Playoffs

Playoffs

- Maximize our alliance's score to win all matches so we can win the tournament

Ranking Point Optimization

RP (qty)	Definition	Robot Requirement
Win (3)	Win the match, score the most points	• High efficiency scoring, resilient to defense: Focus on L3 and L4 of Coral onto Reef
Auto (1)	All robots leave the Barge zone, also score at least 1 Coral in the Reef during autonomous period	• CheesyCare team helps partners to ensure all move • Be able to score 3+ Coral in auto
Coral (1)	Score at least 5 coral of all 4 levels of Reef (or 3 levels with Coopertition Bonus)	• Fast, optimized Coral scoring onto Reef • Be able to score Algae into Processor to assist with Coopertition
Barge (1)	Score at least 14 points via the Barge during the Endgame	• Be able to climb the Deep Cage (12 pts) to maximize our contribution to this RP

GAME ANALYSIS

Robot Quality	Subsystem Requirements
Move quickly	• Gear Drivetrain to minimize driving time for our average cycle length
Minimize distance and rotations needed	• Intaking direction is opposite scoring side • Intake from Feeder • Intake from floor
Never miss/drop Coral	• Passive alignment with End Effector
Acquire and Score instantly: no time spent lining up	• Software assisted auto alignment • Large funnel for Feeder acquisition • Wide intake for floor acquisition
Score on all levels of the Reef	• End Effector positioning (Elevator range of motion) • End Effector placing requirement (Reef pipes are at different angles)
Score Algae into Barge (never miss)	• Lift and shoot lightly, don't shoot from floor • Algae scoring with End Effector • End Effector positioning (Elevator range of motion)
Remove Algae from Reef	• Algae removing End Efector
Move quickly, out position instead of push through opponents	• Drivetrain speed/acceleration • Bumpers are slippery against walls and opponent bumpers
Be able to push through opponents if needed: Maximize traction	• Grippy drivetrain wheels • Maximize total robot weight for max traction • Firm and low bumpers to not ride up on others
Align to and climb on Cage quickly	• Powered wheels to grab and force Cage into latch • Software assisted auto alignment • Engage climber in <1s and winch climb in <1s

SUBSYSTEM STRATEGY

Drivebase
- Due to short cycles, low speed, high acceleration gearing swerve drive
- Maximize base dimensions to prevent tipping

Intake
- Pickup Coral from floor without jamming
- Funnel Coral and reorient it; be able to intake Coral in any orientation
- Full-width to maximize intaking area
- Over-bumper Intake deploys <0.5s

Indexer
- Pass and align Coral from Intake and Funnel to End Effector in <0.5s

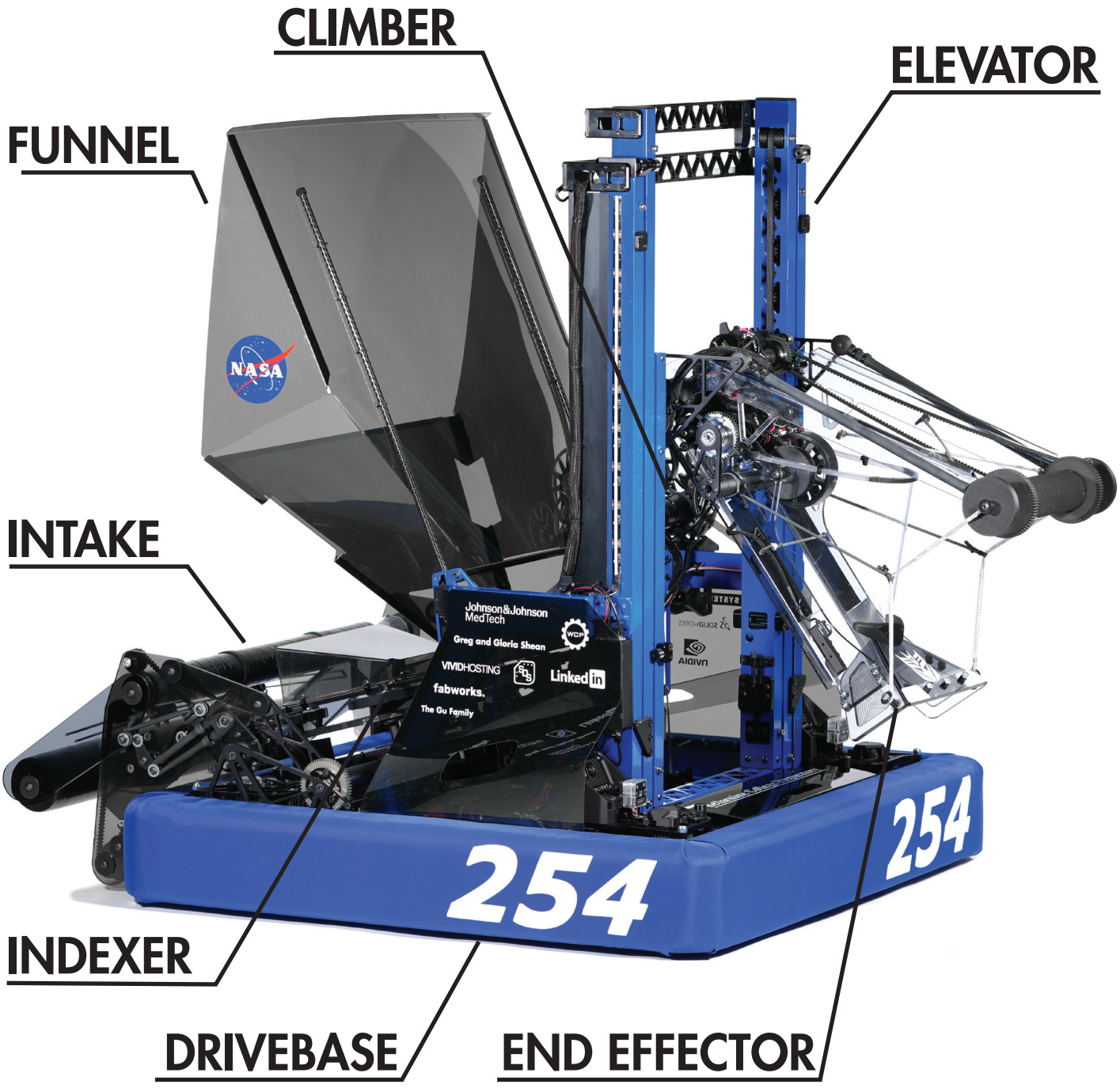
Funnel
- Passively intake Coral from Coral Station
- Steep angle to pass Coral through in <1s

Elevator
- Fully extend in <1s
- Reach L2, L3, L4, and Barge scoring heights
- Stiff; to enable accurate End Effector positioning

End Effector
- Hold and eject Coral onto Reef
- "Flying V" wedge to align Coral to Reef pipe
- Intake Algae from floor and Reef; eject into Processor and Barge

Climber
- Climbs the Deep Cage
- Align in <1s
- Climb in <1s
- Don't contact chain to ensure legal climb

UNDERTOW


CLIMBER
ELEVATOR
FUNNEL
INTAKE
INDEXER
DRIVEBASE
END EFFECTOR
NASA
Johnson&Johnson
MedTech
Greg and Gloria Shean
VIVIDHOSTING
fabworks.
The Gu Family
LinkedIn
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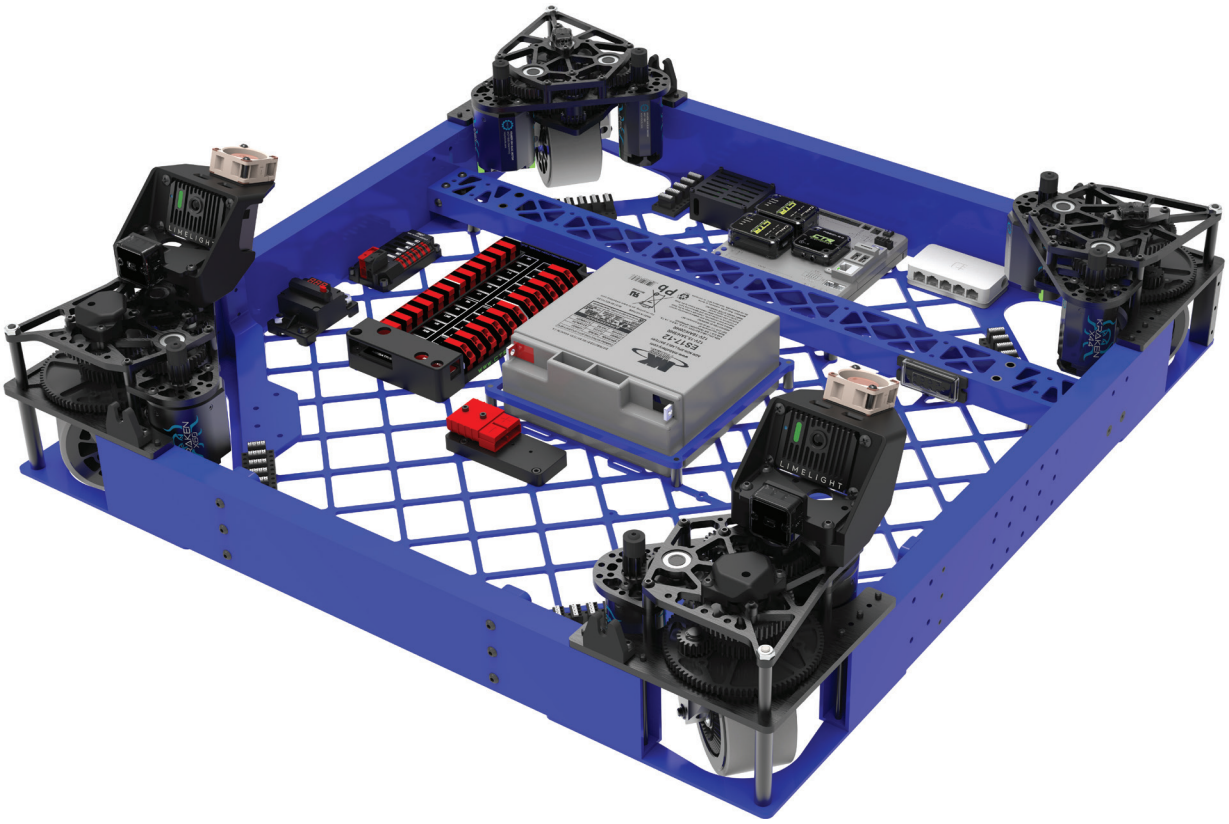
254

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.

WCP X2i Swerve Modules

- 10T X1 drive reduction (~13.2 ft/s free speed) with 4" WCP molded grip-lock wheels
- Previous years used SDS Mk4i, switching to WCP due to 2" wide grippier wheel and azimuth using gear instead of belt

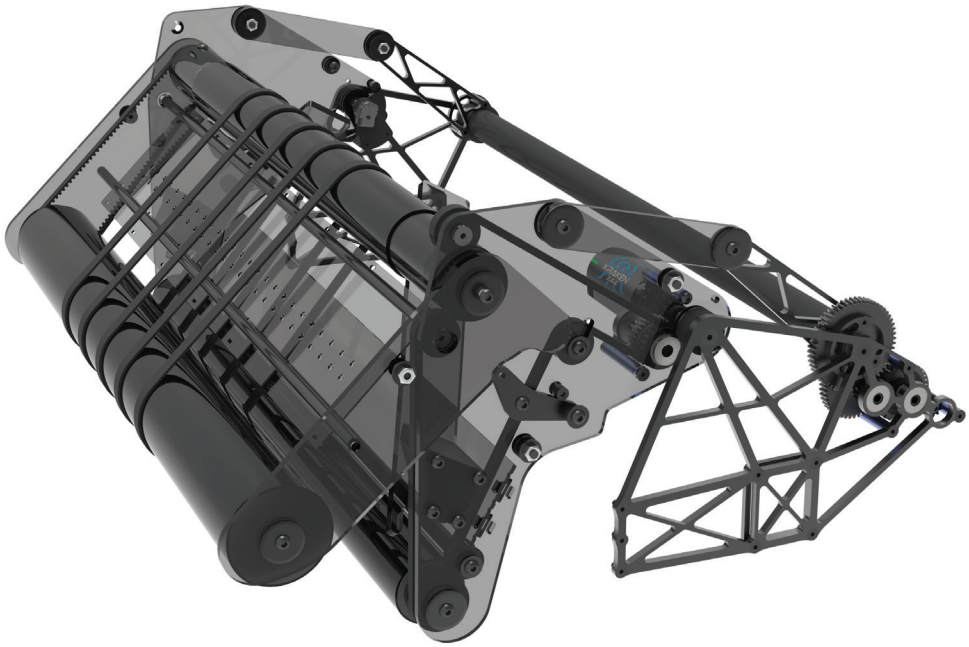
Chassis

- 29.5" x 29.5" frame outer dimensions
- 3" x 1" x 1/8 " aluminum tubes are stiff and lower bellypan (1/8" aluminum) to 5/8" above the floor to reduce CG

Electronics

- Battery centered between Elevator and Intake to balance CG
- Qty 2 Limelight 4s and CANrange sensors mounted on modules
- Limelights have heatsinks and fans to keep cool
- PDP 2.0, with 40A breakers for all 18 motors

INTAKE



The Intake gets Coral off the ground and into the Indexer. Uniquely constructed rollers consisting of rubber tubing on foam create smooth, light, and continuous intaking surfaces.

Structure

- 1/4″ polycarbonate and 1/4″ aluminum plates
- 1/4″ polycarbonate and 3DP wedges funnel Coral to indexer width
- Pivots use 1/4″-20 bolts, aluminum spacers, and fender washers to robustly distribute loads and not crack polycarbonate plates

Rollers

- 3″ Front Roller (silicone tubing on foam on polycarbonate tube deadaxle)
  - Floating on bi-stable sprung plate, opens to intake long-ways coral, and collapse when colliding with wall and for fitting in frame perimeter
- 2″ Kicker Roller (silicone tubing on foam on polycarbonate tube deadaxle)
- 2.125″ Top Roller (silicone tubing on polycarbonate tube deadaxle)
- Rubber bands act as flat belt pulling Coral through deadspots and up ramp
  - Belts guided by printed rollers on bearings, held by zipties
- Powered by 1 Kraken x44 with 13:28T gears then 18T:22T double-sided timing belt for ~15 ft/sec surface speed

Deploy

- Kraken x44 geared to 10:36T then 14:42T then 14:56T to deploy in ~0.15sec
- Gear drives 4-bar linkage to enable pivot near front of robot
- 1.25″ 0.03″ wall aluminum tube jackshaft, behind drive modules

INDEXER

The Indexer reorients Coral from the Intake and Funnel and aligns it for hand-off into the End Effector.

Structure

- ¼″ aluminum baseplate covered by 0.045″ polycarbonate creates floor
- 3DP wedges straighten alignment of Coral for handoff to End Effector
- 3DP yoke holds flex wheel for flattening Coral at handoff into End Effector

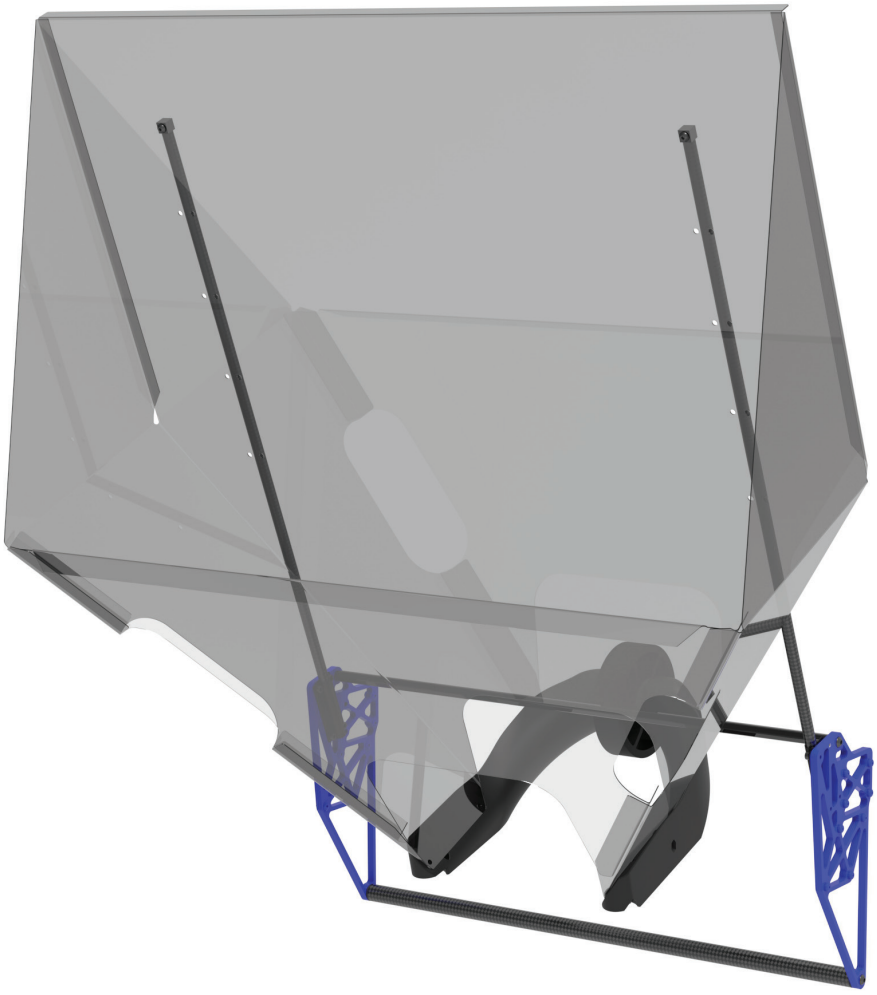
Wheels

- 8x 4″ flex and star silicone wheels on 3DP pulley hub deadaxles
- Wheels feature cut rims and spokes to prevent jams and optimize weight
- 1/8″ bent top polycarb hood directs Coral down during Intake handoff
- Kraken x44 powers 8:48T gears then 1:1 belts for surface speed of 4″ wheels ~30 ft/s

Electronics

- 2x Banner beam break sensors located at the front and rear of Indexer inform software state machine

FUNNEL



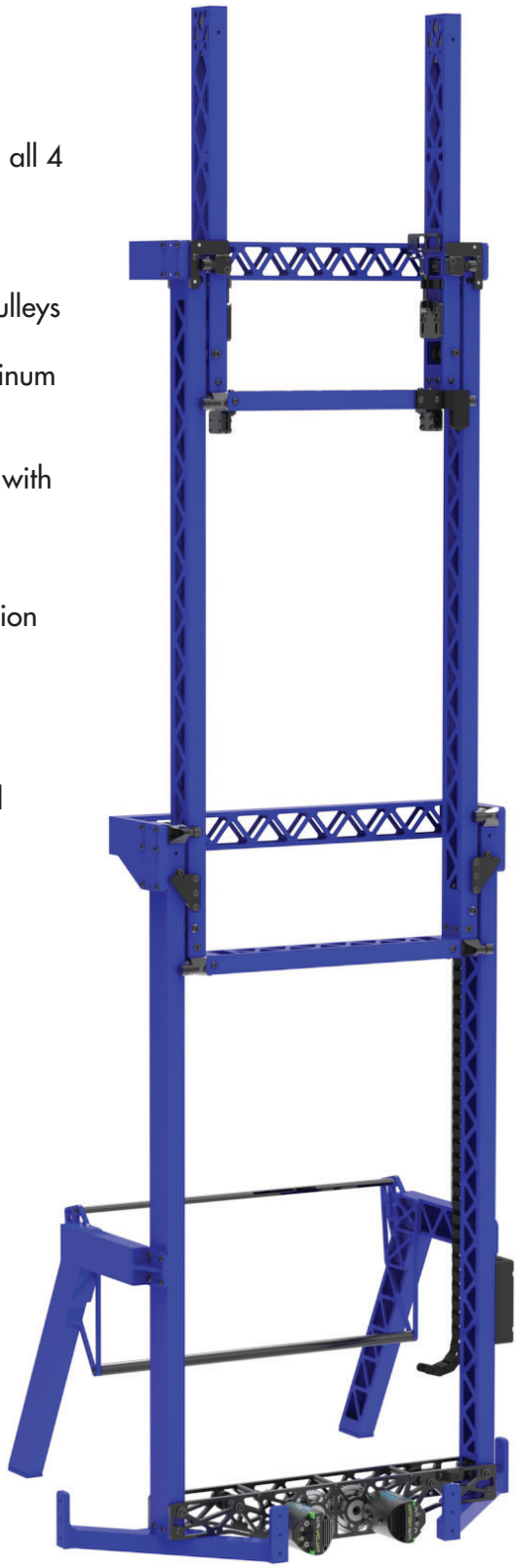
The Funnel catches Coral from the Coral Station and passes them into the Indexer. It enables an alternate intaking method for autonomous or redundancy if Intake breaks.

Structure

- Made of 1/32″ Polycarbonate, edge bends for stiffness
- Stiffened by 3/8″ Carbon Fiber Rods with aluminum end plugs
- CF rods mount by 4 billet aluminum clamps off of the Elevator A-frame
- Steep 50° angle for greater funneling speed
- 3DP yoke holds flex wheel for flattening Coral at handoff into End Effector
- Can intake coral when bumpers are 1 foot away from Coral Station wall

ELEVATOR

The Elevator lifts the End Effector to enable swift scoring on all 4 levels of the Reef and into the Barge.



Elevator

- 2x Kraken X60's drive 11:50T gears and then 36T pulleys acting as drums
- A-frame tube comprised of welded 2x1x1/16" aluminum tubes stabilize the Elevator and mounts the Climber
- Elevator Uprights, Intermediate Stage, and Carriage comprised of 2x1x1/16" aluminum tubes connected with tube plugs and bearing blocks
- 2 Stage, Continuous Rigged, Belt Driven (9mm-wide, 5mm-HTD) inside the tubes
- SDS Elevator Bearing Blocks or customized billet version hold track rollers to provide guidance
- Travels full ~52" range of motion in ~0.3s

Electronics

- Hall Effect Sensor travel zeroes position when stowed
- Igus Energy Chain guides wires, mounted opposite Climber to avoid Cage

CLIMBER

The Climber features a roller claw with a latch that can grab the Deep Cage and then a winch pivots the Claw to pull the robot under the Cage and off the ground.

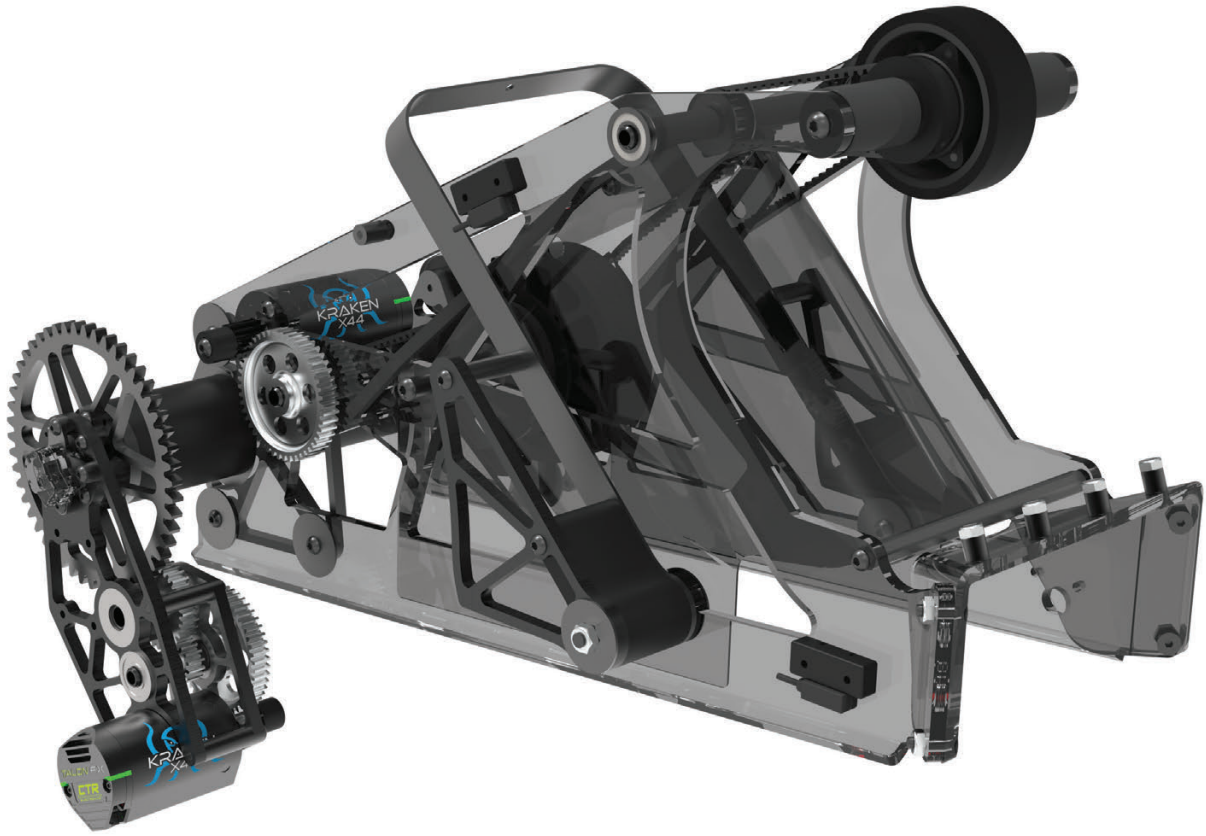
Roller Claw

- 1/4" aluminum plates hold wheels and pivot
- Deployed with 30 lbf gas spring
- 2x 4" OD 60A flex wheels are grippy and grab vertical pipe of Cage
- Kraken X44 powers via 10:30T gears then 15:28T belt
- Plates direct Cage away from Funnel and Elevator
- CANcoder measures claw deploy position

Gearbox

- Winch is remoted to bellypan for lower CG
- Kraken x60 powers 1:224 Gearbox
- Ratchet and pawl holds the robot up after match ends
- Dyneema rope spools on ½" hex shaft

END EFFECTOR



The End Effector receives Coral from the Indexer and places it onto the Reef with the help of an auto-aligning "Flying V". Another wheel intakes Algae from the Reef or Floor. The End Effector's Wrist enables reaching into the Reef or up to the Barge.

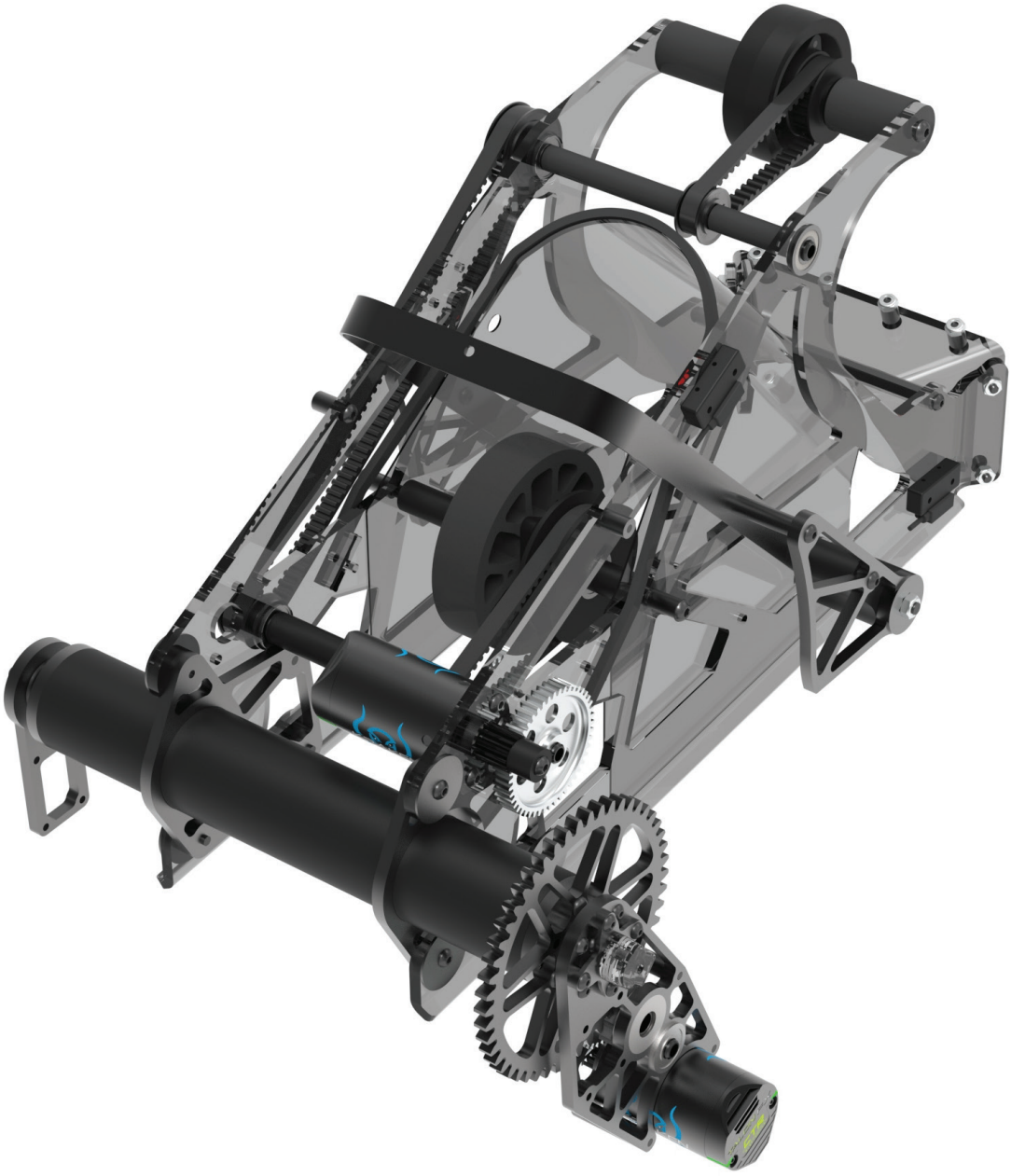
Wrist

- Kraken X44 powers pivots with 10:48T + 14:32T 20DP gearbox, then 10:40T 10DP sector gear to enable 210° rotation in ~0.2s
- Gear-to-hex interfaces shimmed or custom shafts to eliminate backlash
- 2" OD tube with welded endplugs and mount plates is stiff live axle
- CANcoder 1:1 on pivot provides axis absolute position

Coral

- 0.035" polycarbonate Hood and 4" 60A flex wheel holds Coral
- Kraken x44 powers 12:48T then 15:36T belt to spin wheel at a surface speed of around ~13ft/s for rapid scoring
- "Flying V" wedge aligns End Effector to tip of Reef pipe for never-miss fast scoring
- 2x Banner beam break sensors trigger to enable positioning of Coral with flex wheel and triggering of Pipe for automatic scoring exhaust
- Back of Hood has a Hoop that is sprung out of way to enable L1 scoring via passthrough, but a cam drives into being a hardstop during Indexer handoff

END EFFECTOR

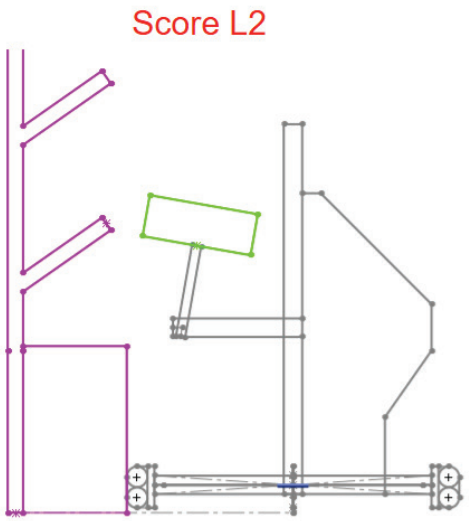


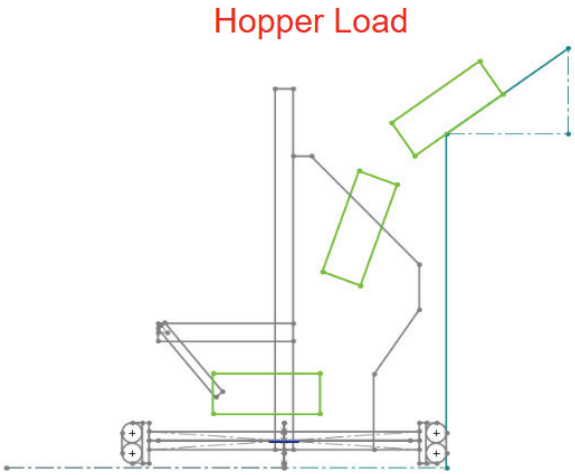
Algae

- 3″ 40A stealth wheel and bottom grippy studs grab Algae
- Shared motor with Coral, powers wheel via 12:48T gear then 15:24T + 15:25T belts
- Flexible polycarbonate sideplates for compliance and impact resistance

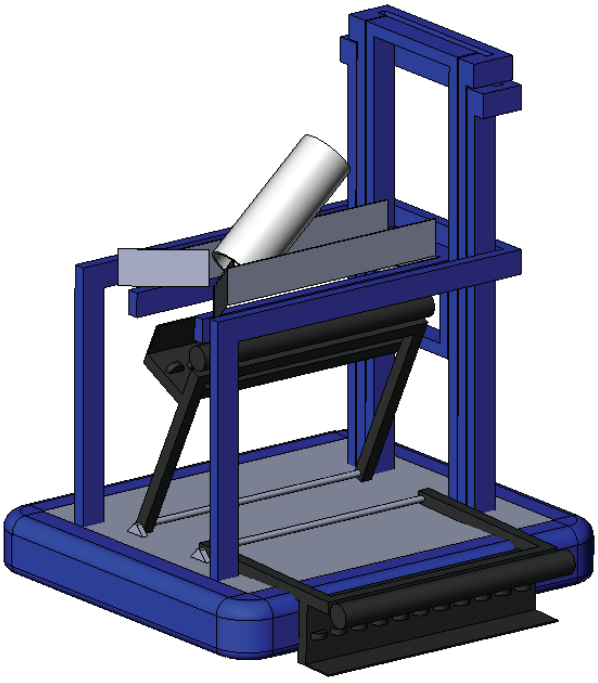
ARCHITECTURE

Alternate architectures that were considered but ultimately not selected:

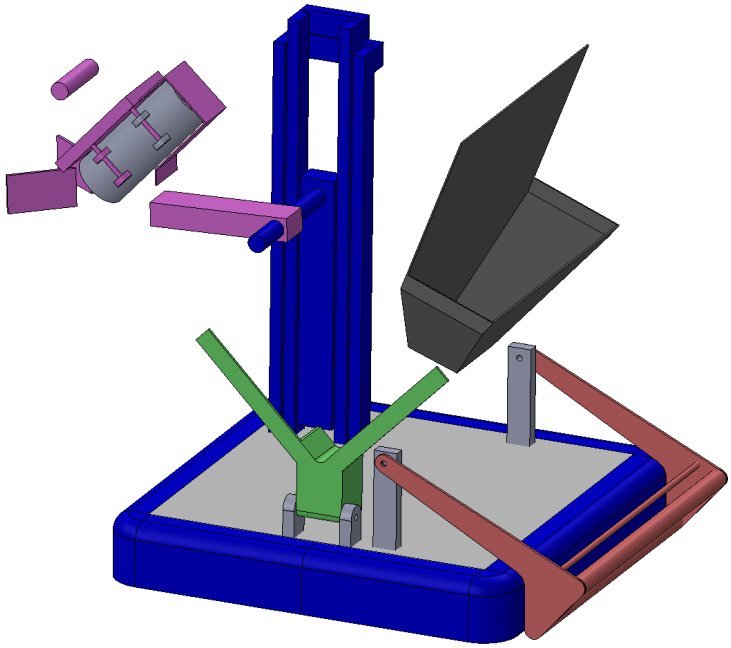




Wrist Dunk + Funnel + Passthrough



Dual Intakes flip-up to Laterator



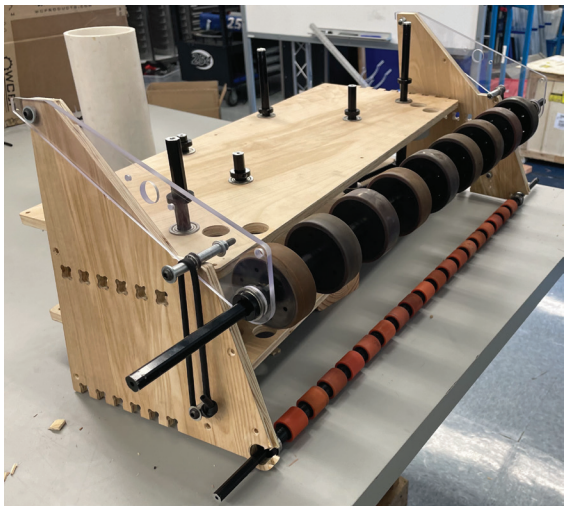
Side Elevator with Intake, Funnel, Climber, and Wrist

PROTOTYPING

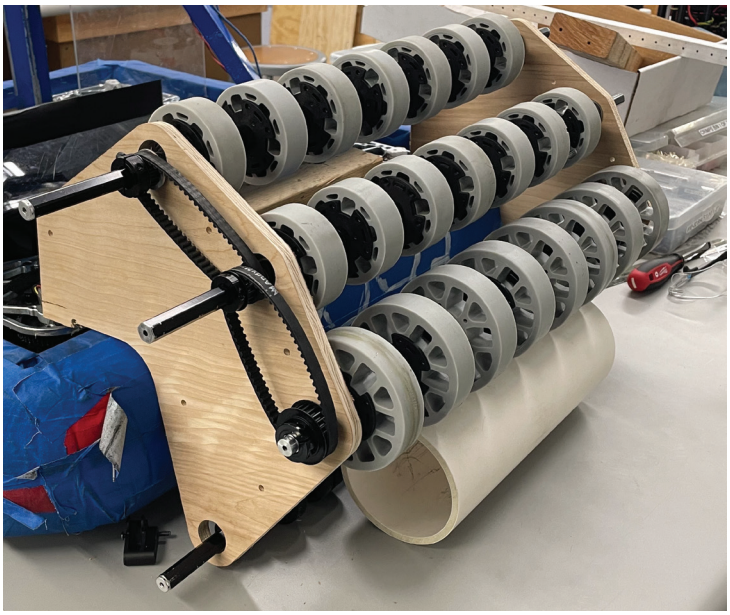
Some of the protypes used to evaluate subsystem designs:

Roller Claw

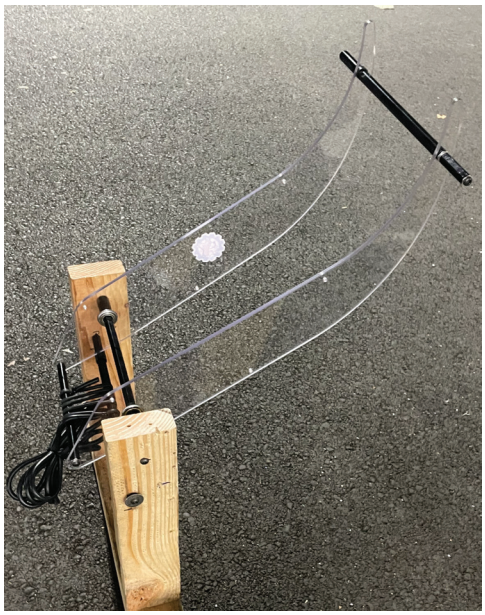
V Indexer



Intake



Algae Catapult



ALPHABOT

To learn more about Reefscape and certain robot architectures, the team quickly built a simple robot to play the game. Using our 2023 Elevator and Drivebase, with a new Carriage, Arm, and Roller Claw, the team was able to build the 2025 AlphaBot in 1 week.

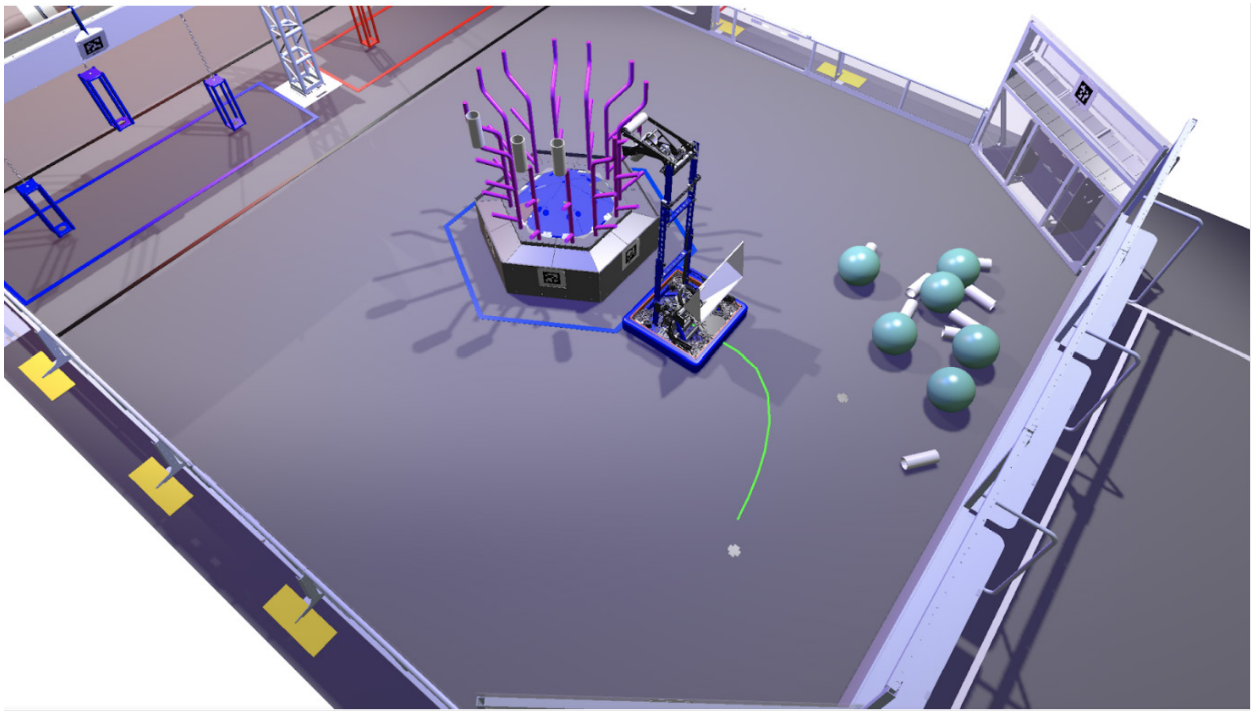
Goals

- Serve as a quick, initial robot to understand gameplay and dynamics
- Learn what to do and what not to do
- Provide a robot for software to develop auto paths, auto aligns, and vision to port over to competition bot

What we learned (both good and bad)

- An End Effector without auto-align compliance is prone sometimes missing and dropping Coral
- A pivoting arm motion requiring elevator and arm coordinated scoring motion is slower than something where you can just drive into Reef
- A small roller claw is too narrow for effective intaking directly from Coral Station
- Limelight camera placement must be set-back from corners to still see tags when near the Reef
- Shielding is needed to protect sensitive drivebase electronics from dropped Coral

AUTONOMOUS



During the 15-second autonomous period, the robot scores Coral onto the Reef following pre-generated paths.

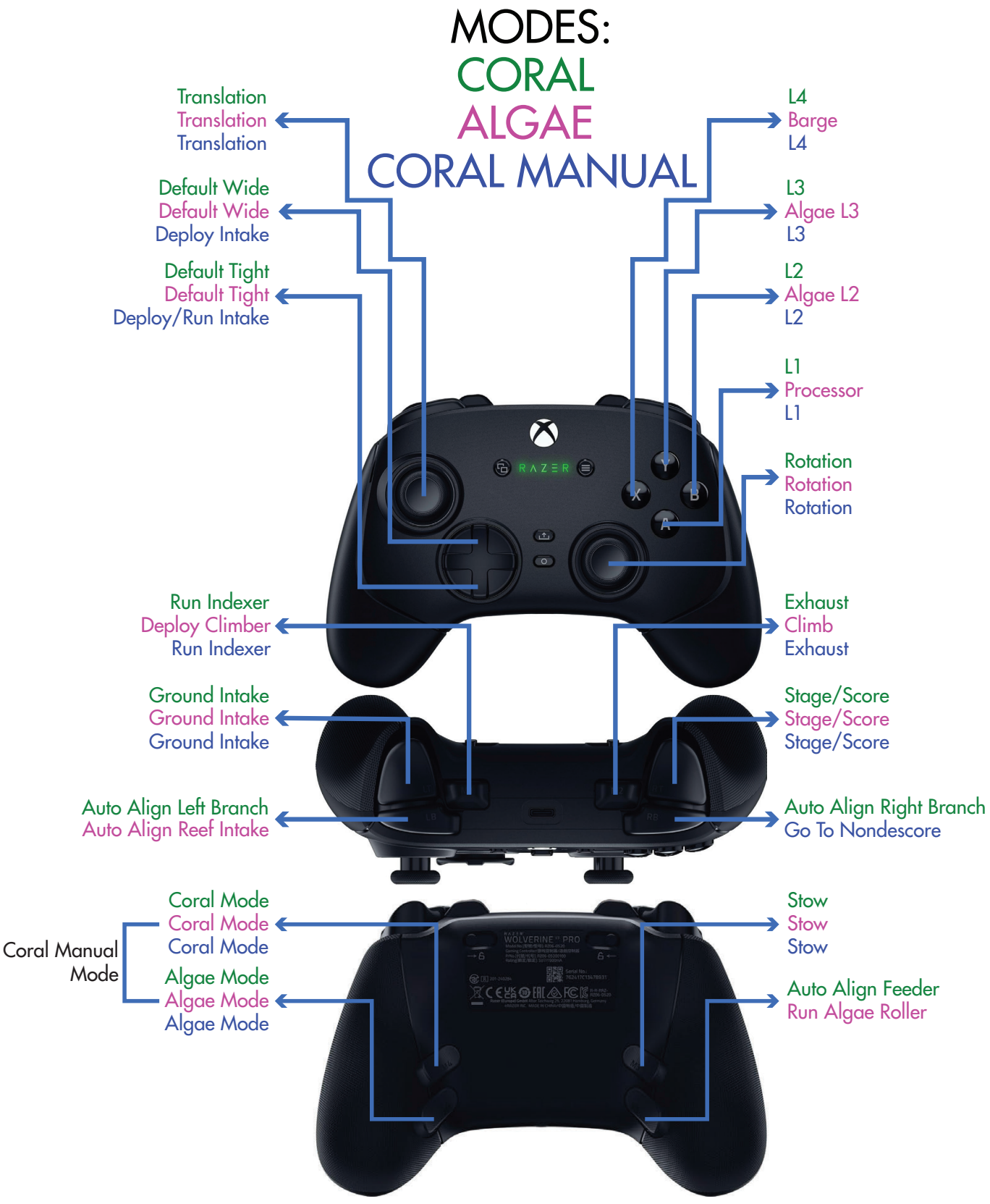
Path Generation

- Driver chooses a custom scoring sequence via driver station dashboard selector
- Algorithms (A* and AD*) generate optimized Reef paths in real time with collision avoidance and dynamic obstacle detection (such as the Reef)

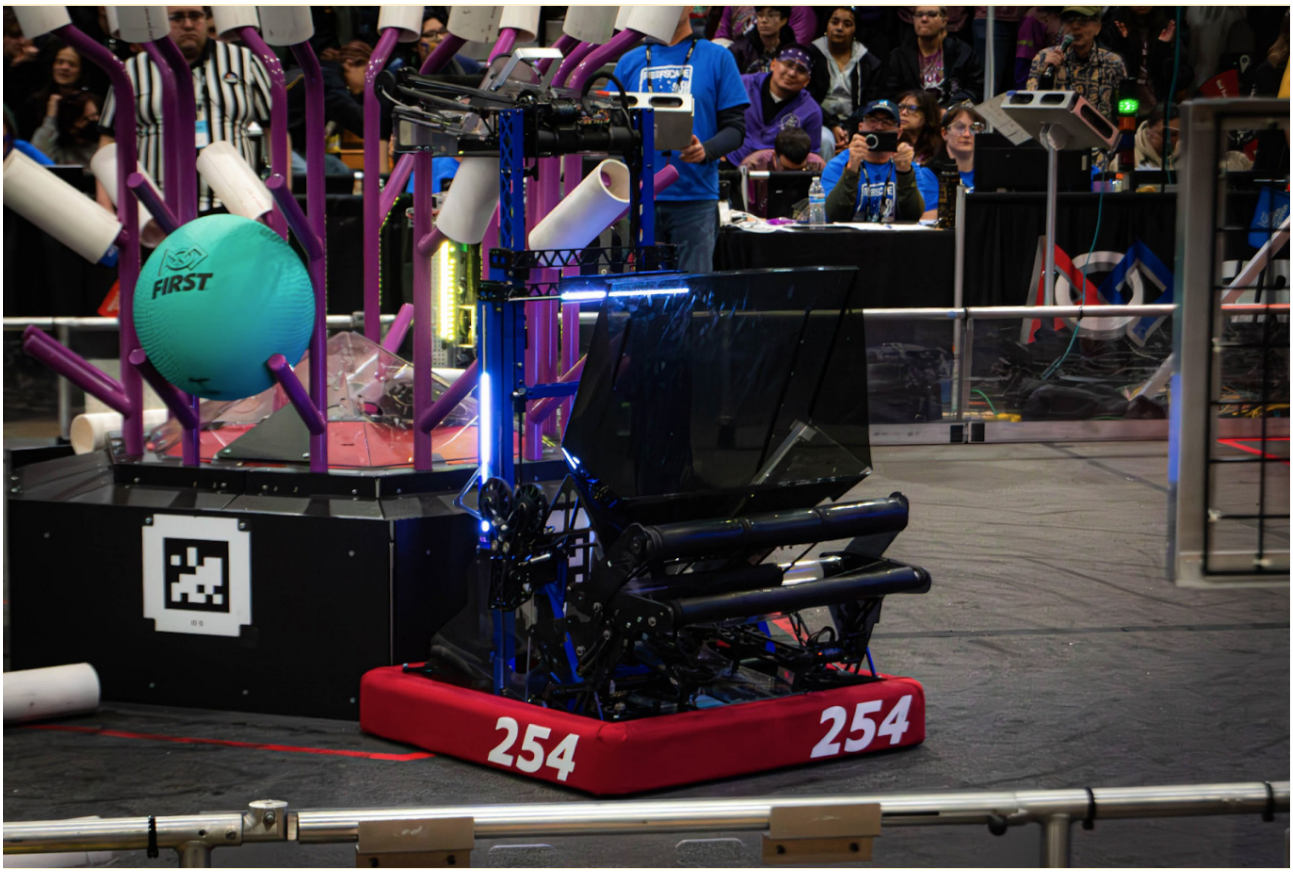
PathPlanner

- Constructs complete trajectories which execute all of the in-path scoring events along specified path
  - Pre-computed paths, such as Feeder to a given Reef branch, are cached during robot initialization and merged with on-the-fly paths
  - Simple mirror enables paths for red vs blue Alliances

TELE-OP


MODES:
CORAL
ALGAE
CORAL MANUAL
Translation
Translation
Translation
Default Wide
Default Wide
Deploy Intake
Default Tight
Default Tight
Deploy/Run Intake
L4
Barge
L4
L3
Algae L3
L3
L2
Algae L2
L2
L1
Processor
L1
Rotation
Rotation
Rotation
Run Indexer
Deploy Climber
Run Indexer
Exhaust
Climb
Exhaust
Ground Intake
Ground Intake
Ground Intake
Stage/Score
Stage/Score
Stage/Score
Auto Align Left Branch
Auto Align Reef Intake
Auto Align Right Branch
Go To Nondescore
Coral Manual Mode
Coral Mode
Coral Mode
Coral Mode
Algae Mode
Algae Mode
Algae Mode
Stow
Stow
Stow
Auto Align Feeder
Run Algae Roller

TELE-OP



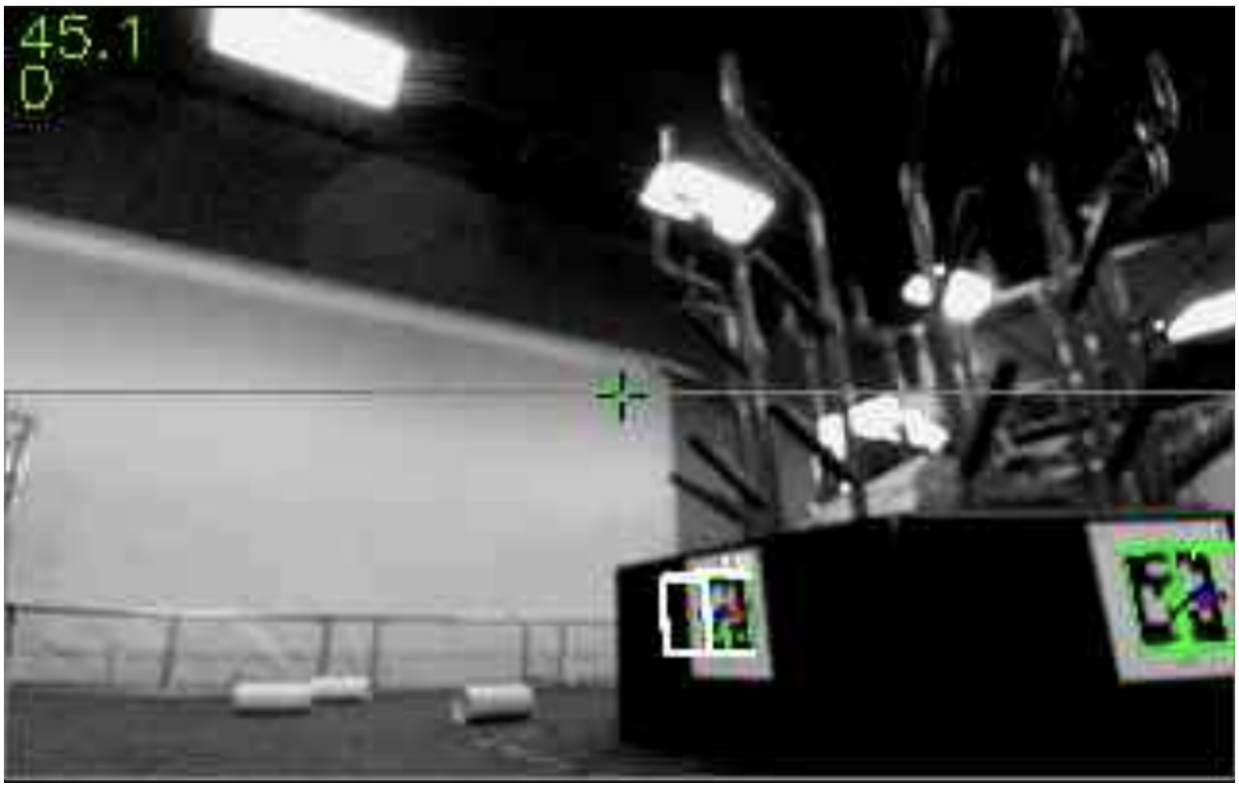
Software allows the single driver to intake and score Coral and Algae, and climb with smooth, responsive controls. Subsystems operate under a centralized state machine, allowing the driver to focus on timing and game flow.

- Driver select a mode for the state machine:
  - Coral Mode (Intake and Scoring with set poses)
  - Coral Manual Mode (direct mechanism control)
  - Algae / Climb Mode (algae scoring and endgame climbing)
  - Superstructure automatically and quickly transitions subsystems between modes
- Coordinated motion between Elevator and Elevator Effector enables rapid Coral placement
  - Subsystem presets allow for repeatable, high-speed cycles

Heading Controller

- Field-relative swerve drive with heading snap for auto-alignment
- Slew rate, velocity, and acceleration constraints reduce skidding and drift
- Heading controller maintains robot orientation while strafing or scoring

LOCALIZATION



Localization combines Limelight camera vision with drivetrain odometry to know the position of the robot on the field. This enables various functions such as auto-align scoring and obstacle avoidance.

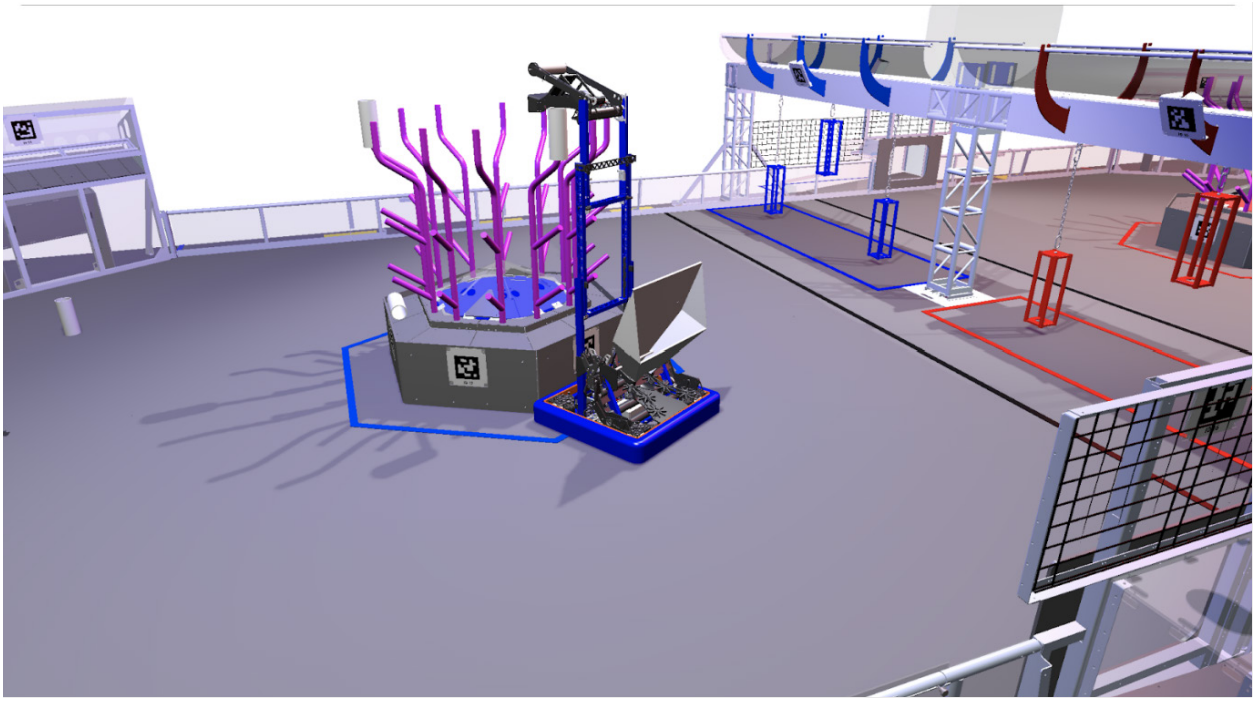
When near AprilTags

- Process AprilTag detections with Limelight's MegaTag 1 algorithm for full robot pose estimation which uses both cameras for better tag visibility and accuracy
- Validation checks on tag count, area, and ambiguity ensure reliable measurements

When farther from AprilTags

- Rely on swerve drive odometry (drive encoders and gyro) for continuous position tracking
- Periodic vision updates correct any accumulated odometry drift

SIMULATION



New this year, the team utilized Maple-Sim integrated with AdvantageScope to simulate subsystem movements and test new software, especially autonomous paths, without the need for the physical robot.

Maple-Sim

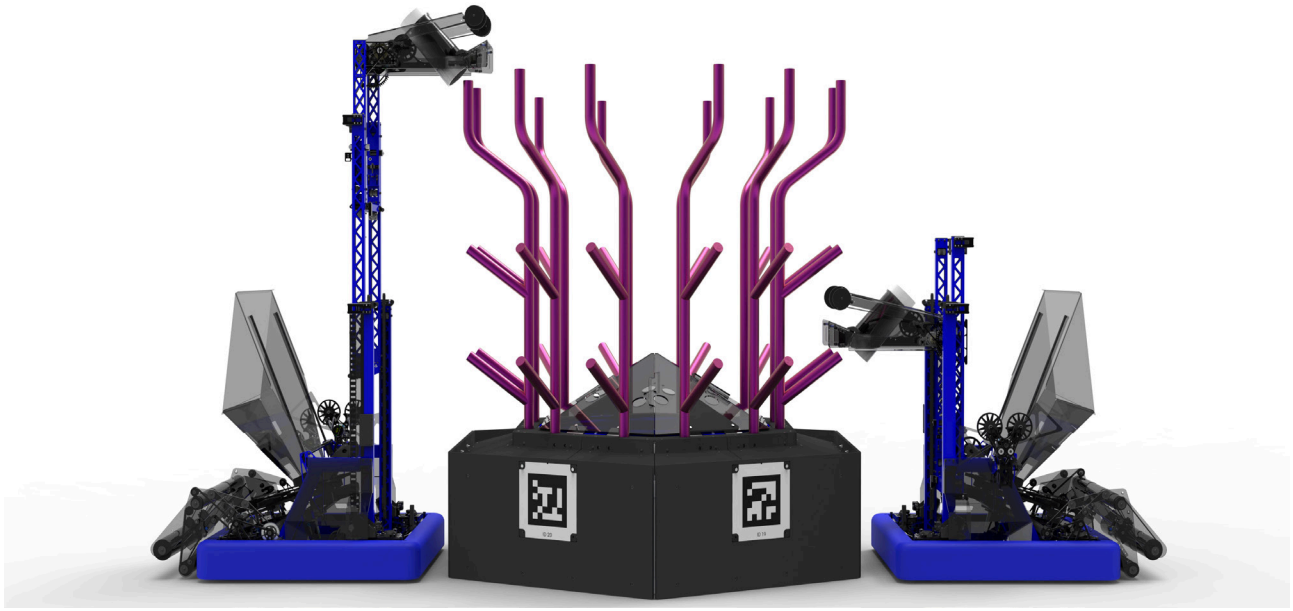
- High-fidelity physics engine simulating robot-field interactions for realistic game piece and scoring element behavior
- Complete swerve drive modeling with motor characteristics and configurable friction coefficients
- Real-time collision detection and game piece manipulation testing

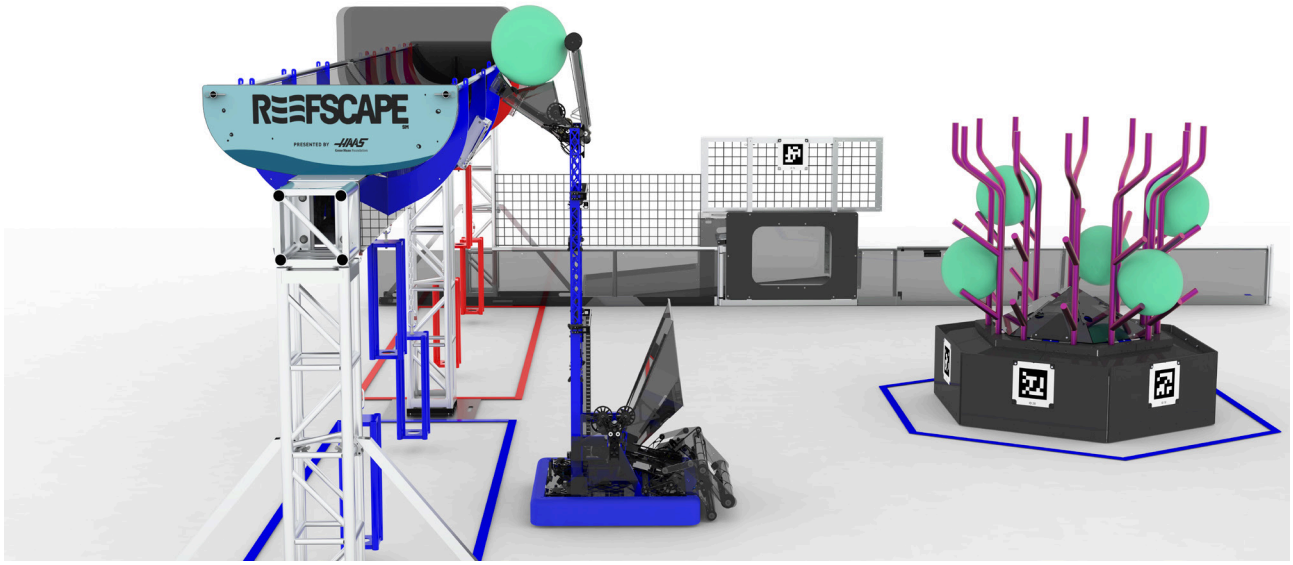
Advantage Scope

- Stores robot logs and visualizes data, useful for post-match analysis
- Live robot telemetry for vision and drivetrain validation

Simulation Accuracy

- Imported robot 3D model with fully articulating mechanisms
- Subsystems complete with masses, moments of inertia, and gear ratios
- Realistic vision simulation using PhotonVision with AprilTag detection




REEFSCAPE
PRESENTED BY HAAS