DREADNOUGHT

254

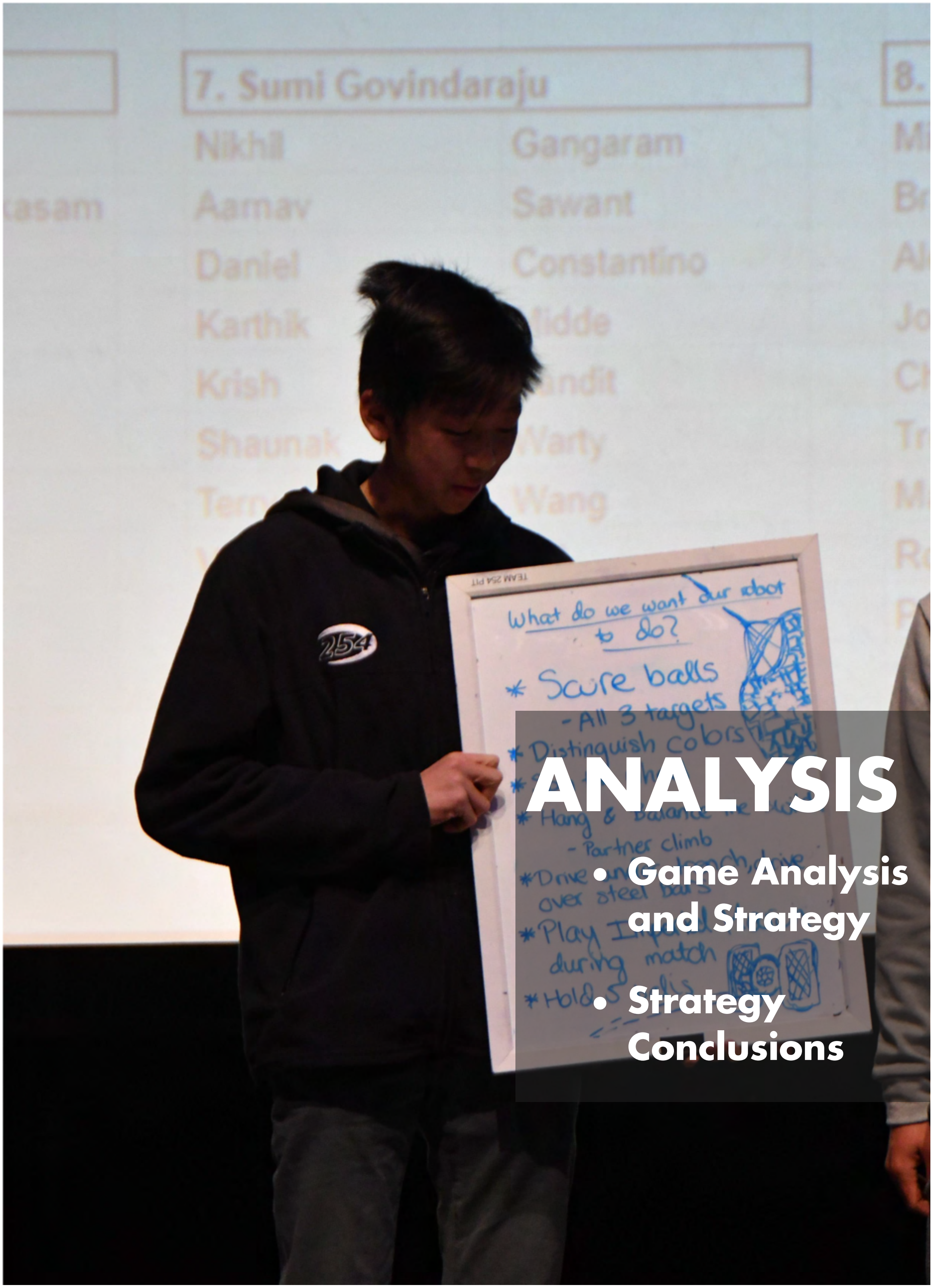
2020 - 2021

Technical Binder

Foreword

Our season started with a few members attending our local FIRST kickoff and the rest of the team viewing the live-cast from our lab. The subsequent game analysis helped the team determine the optimal strategies and robot requirements. With these requirements, extensive prototyping on all subsystems was conducted in the first few weeks until final robot designs and manufacturing were completed towards the end of the build season. This Technical Binder details the game analysis, decisions, outcomes, and technical designs that guided us from kickoff to our current robot for the 2020 - 2021 FRC Season: *DREADNOUGHT*

TABLE OF CONTENTS



ANALYSIS

- Game Analysis and Strategy
- Strategy Conclusions

GAME ANALYSIS

This year's game introduced a lot of challenges, the largest of which is the main game aspect, the power cells. The dynamic field layout and new zone penalities only make it more difficult to consistently score. Apart from ball scoring, the trench could prove to be a hindrance to cycle times and maneuverability and provides the choice to design a robot that can fit under the trench but lose height that can help climb onto the shield generator. With the abundance of game aspects this year, it becomes apparent that some teams might not have the ability to interact with them all, which makes a jack-of-all-trades robot the best choice for a team that is aiming for the World Championships.

Below we outline the prioritized requirements set before designing our robot.

Shooter/Turret

1. Reliability (>95%) shooting in the Outer Port (from shooting locations)
2. Shoot quickly (5 balls in <1 sec)
3. Semi-reliable (>50%) shooting into Inner Port
4. Shooting from at least 35 ft (far side of Trench) into Outer Port

Intake

1. Touch it, own it (grab balls regardless of driving speed)
2. Intake 3 balls at once without jamming
3. Pick up from the floor
4. Intake balls on 1" beams
5. Feeding directly from loading station with intake stowed (bumper-only contact)
6. Backdriveable deployment suspension allows the intake to passively retract in the case of a collision

Serializer/Feeder

1. Hold 5 balls at once without jamming
2. Feed consistently to the shooter
3. Extremely fast serializer, (<2 sec into shooter)
4. Using sensors to index balls

Climbing

1. Climb solo in <2 seconds
2. Climb onto already titled Shield Generator
3. "Buddy climb" (lift a partner who does not have a reliable climber)
4. Triple climb (2 buddy climbs)
5. Level Adjuster (translate along the bar to reposition mass for balancing)

Control Panel

1. Ability to spin the wheel
2. Have a color sensor on the spinning mechanism
3. Spin the wheel while shooting

Autonomous Period

1. Score three preloaded Power Cells (100% accuracy) into the Inner Port
2. Pick up >5 balls and shoot into at least the Outer Port (100% accuracy)
3. Score ≥ 10 balls in the Inner Port to finish Stage 1
4. Pick up all 5 balls in our Trench Run and shoot into Inner Port
5. Overload Feeder Station with more than 15 balls to start a "positive feedback loop cycle"
6. Stealing balls quickly from opponent's Trench run before they can contact us

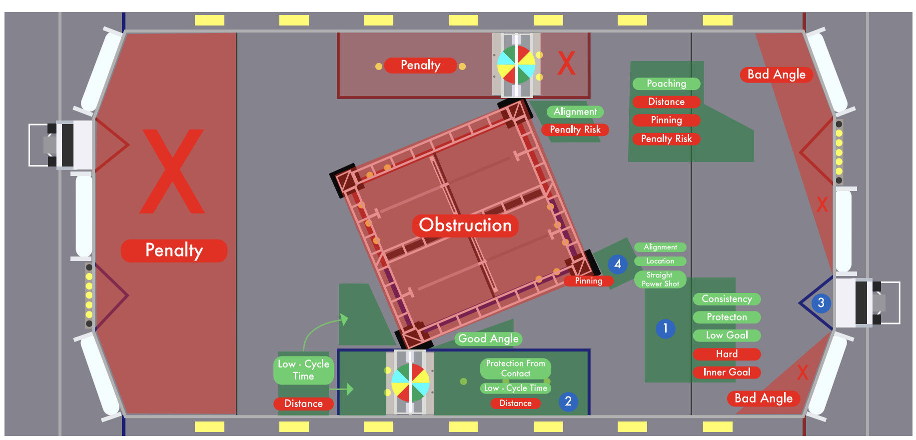
Tele-Operated Period

1. Vision alignment to maximize shooting accuracy
2. Go for the inner port in the Autonomous Period
3. Automated WOF routine using color sensors
4. Driving with closed-loop control during tele-op
5. Shooting while moving
6. Ability to have different types of shots(laser vs. lob)

General Design

1. Two-speed drive gearbox
2. Fast speed for fast cycles (19 ft/s - 23ft/s on high gear)
3. Fitting the robot under the trench for increased maneuverability
4. Maximum weight for pushing power and greater torque with the floor

Game Field Strategy



STRATEGY DECISIONS

General Design

Our overarching goal was to build a competitive robot that wins the FIRST Championship. To accomplish this we need to be able to complete every task without the need for alliance support, allowing our strategy and match play to be as versatile as possible.

We approached our design while prioritizing the ball scoring mechanisms, as they are the central game aspect this year. However, we did not want to compromise on any of the other game aspects, as many of them can be deciding factors in a match.

Autonomous Period

Our goal for the Autonomous Period is to complete the stage 1 objective and also start tele-op with an advantage over the opposing alliance. This means that we want to get around 9 balls while shooting from a region where we can score reliably and accurately into the inner port. Furthermore, if we are on the left side (from the POV of our alliance station), we want to steal the balls from the opposing alliance's trench run, before they can be scored by the other alliance. We also want to take advantage of the balls on the Rendezvous Point, to increase the number of balls that we score.

Tele-Operated Period

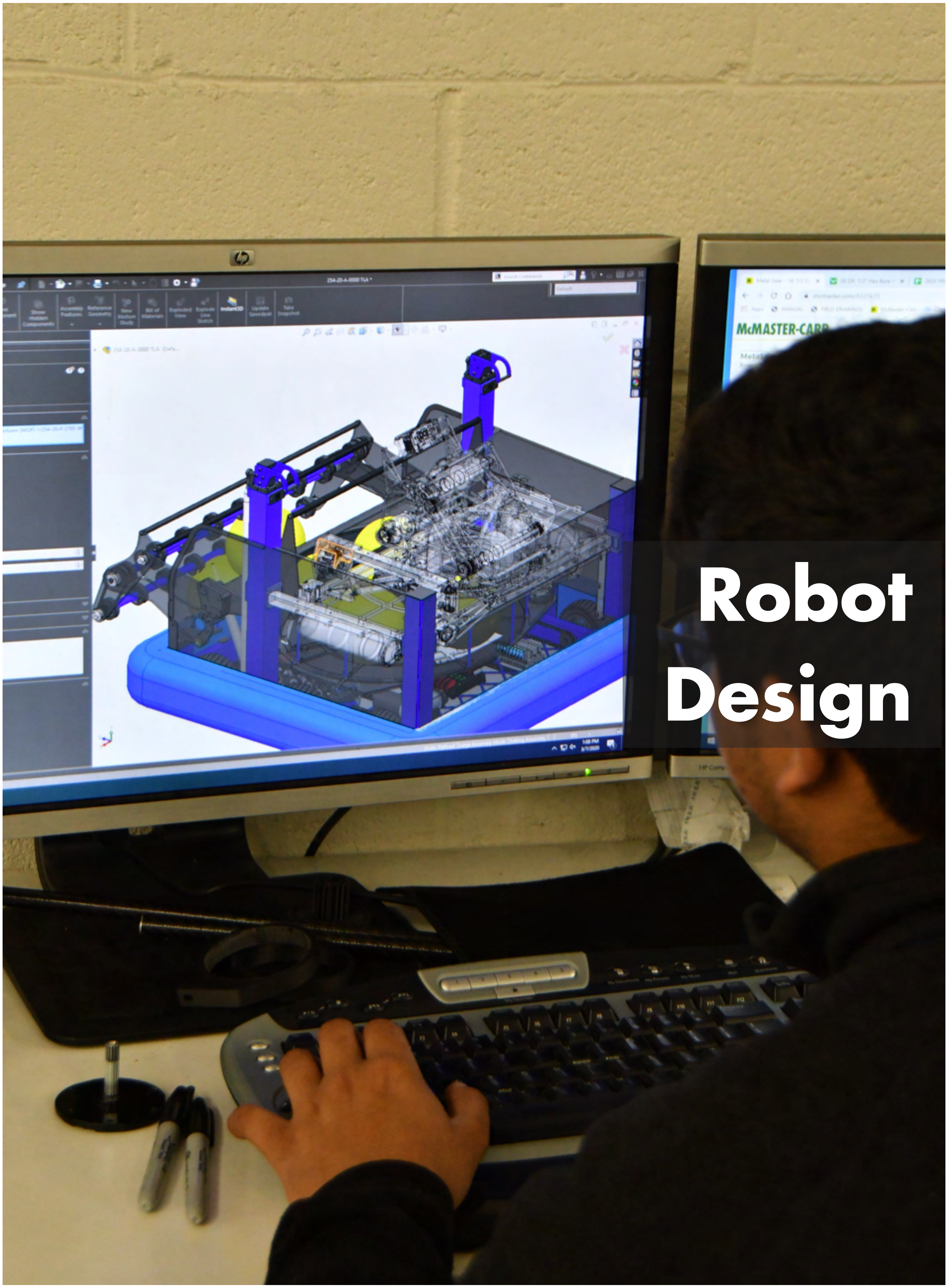
To maintain a strategic advantage, we need to score all 4 ranking points, and to do that our robot must be able to manipulate the Power Cells, Control Panel, and Shield Generator. We agreed that our ideal locations to shoot would be directly in front of the scoring location. We wanted a shooter that is accurate without much driver interaction, and we knew it would be required that we could quickly shoot 5 Power Cells back to back.

End-Game

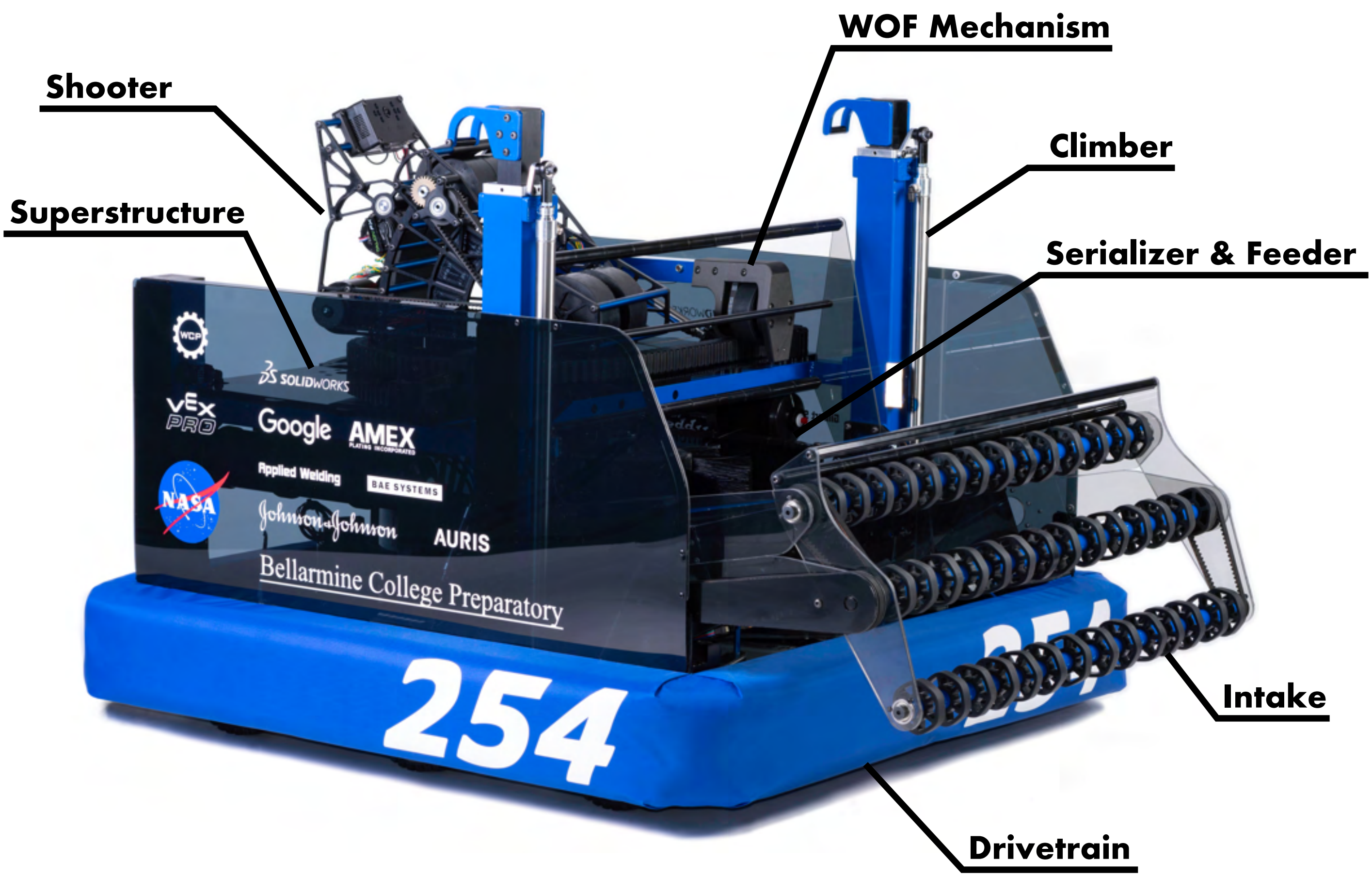
To earn the last ranking point, an aliance can either finish the match with a leveled Shield Generator and two hanging robots, or 3 hanging robots with an unleveled Shield Generator. To keep both options on the table, we decided a buddy climb mechanism (a subsystem that allows an alliance partner to climb with us) would be beneficial to maximize our chances of scoring the Ranking Point.

Kickoff Strategy Group

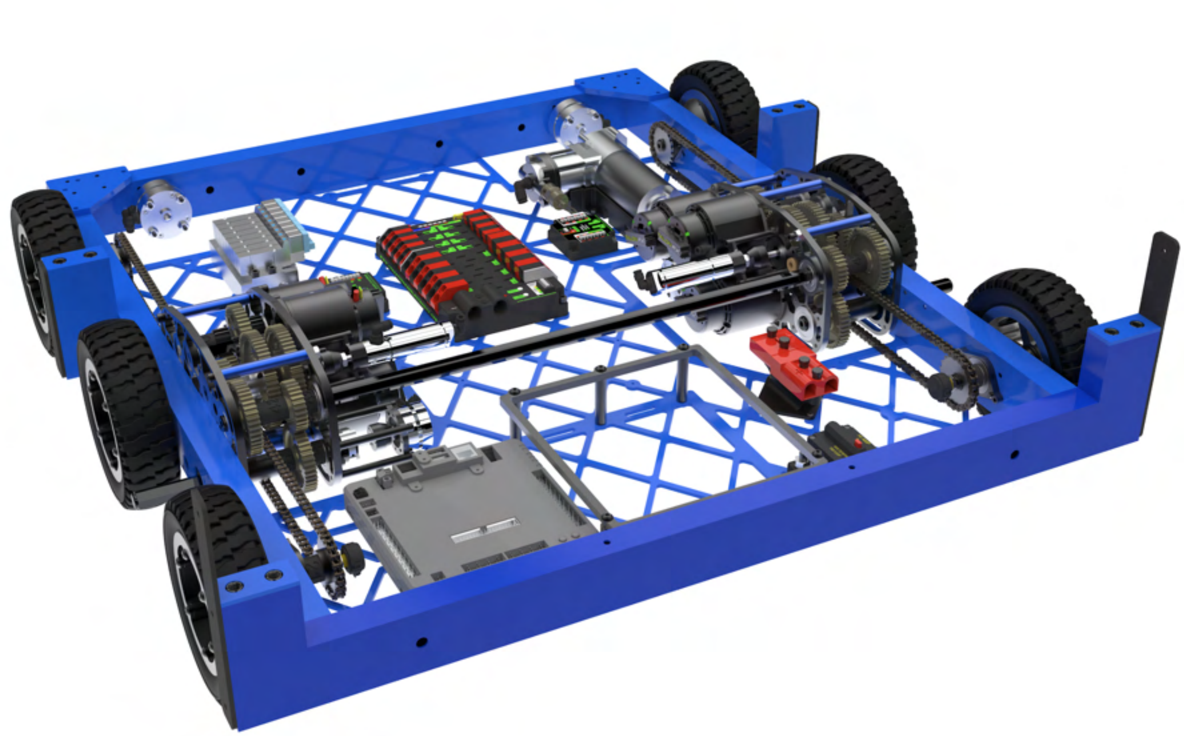
Robot Design



DREADNOUGHT



DRIVETRAIN



The drivetrain allows the robot to maneuver around the field quickly and precisely. This year's design is a "West Coast Drive" which features pneumatic wheels and a square drivetrain. The simplicity, reliability, and power of the WCD has served us for many years. For this reason, we could expend more effort and resources working on other subsystems.

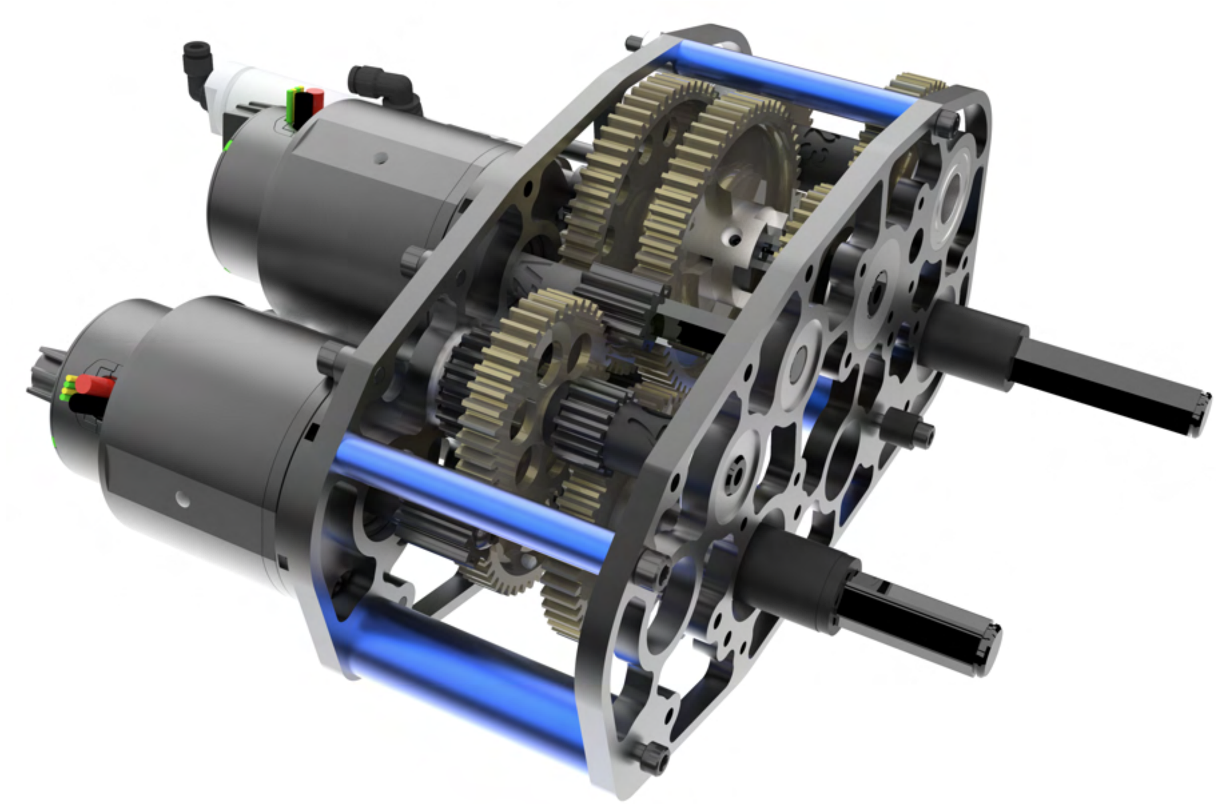
West Coast Drive

- 6 wheels with a 0.08" center drop
- 6" WCP pneumatic wheels for compliance and stability over Rendezvous Point bumps
- 29.75" x 30" welded 2" x 1" x 1/16" aluminum tubing frame
- Easy to mount superstructure
- Maximizes space for electronics and wiring

Square Drive Base

- Narrow enough to go through the trench
- Optimal turning and maneuverability
- Ideal shape for the circular serializer

DRIVE GEARBOX



The drive gearbox provides the reduction from the drive motors to the wheels to power the drivetrain. This year's drive gearbox has two speeds and contains a Powered Take-Off for the climber.

Two Speed Gearbox

- 6 Falcon 500 motors for large amounts of power
- 13:1 Low Gear (13.2 ft/s)
- 8:1 High Gear (21.4 ft/s)
- Low gear provides torque for pushing through defense
- High gear optimized for full-field sprint cycles

Climber Integrations

- Pneumatic actuated dog engages Power Take-Off (PTO) gear train (9.88:1 reduction to 0.75" diameter spool)
- Both gearboxes joined by a 1/2" thunderhex jackshaft across the robot
- Pneuamtic actuated dog brake holds robot up after a match

INTAKE

Our team's philosophy for intake design is "Touch it, own it." This year's intake consists of 3 robot-width horizontal rollers on a pneumatically actuated four-bar to lift up to 3 balls over the Bumper and into our Serializer.

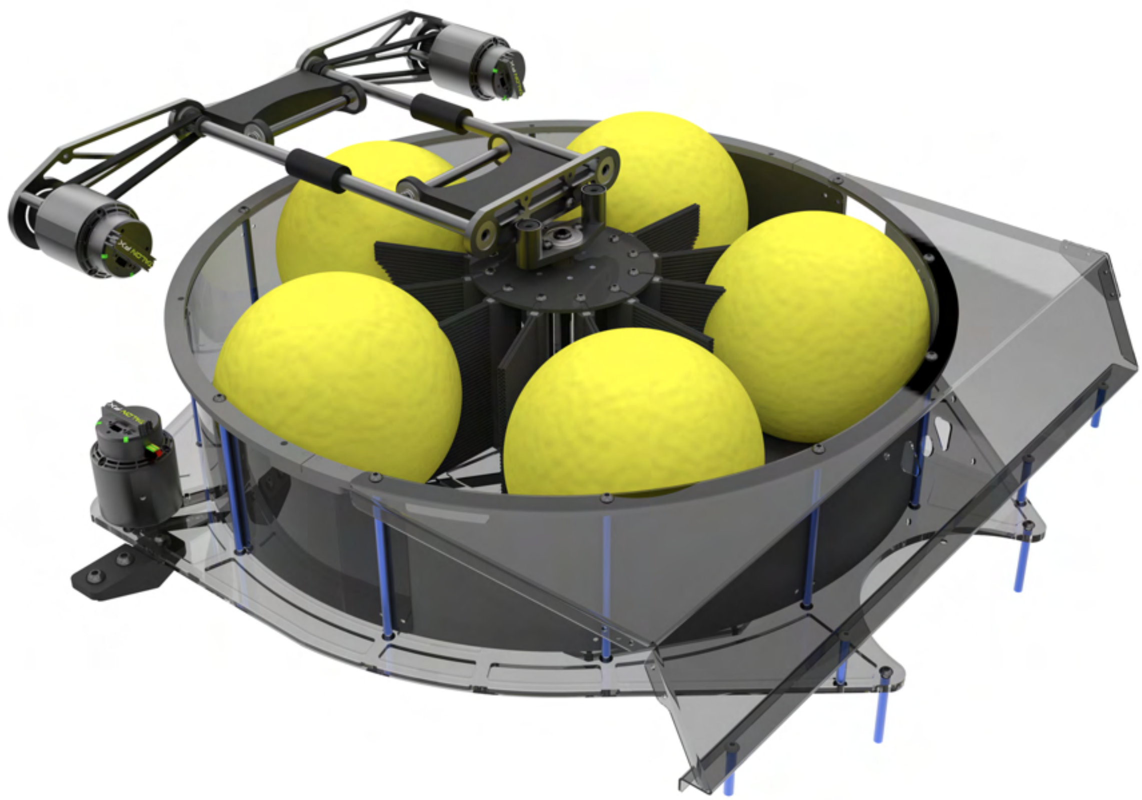
Horizontal Rollers

- 3 belt-driven steel rollers powered by 1 Falcon 500 motor
- High-speed front roller grabs balls off the ground
- Higher torque upper rollers prevent ball jams
- High-speed front rollers grab balls off the ground, while the lower speed (higher torque) upper rollers prevent ball jams.
- 2" black flex wheels provide compliance when liting balls
- Steel tubes prevent deformity

Four Bar Deploy Linkage

- 1/4" thick polycarbonate plates provide durability to withstand impacts
- Non-parallel four-bar optimally positions rollers for ground pickup and human player loading
- 3/4" Bore 3" Stroke Pneumatic Cylinders on each side actuate to stow/deploy
- Can pull back into the robot for maneuverability around defenders

SERIALIZER & FEEDER



The serializer receives up to 3 balls from the intake and indexes up to five balls so that they can be shot rapidly without jamming. The feeder pulls balls out of the serializer circle and into the shooter.

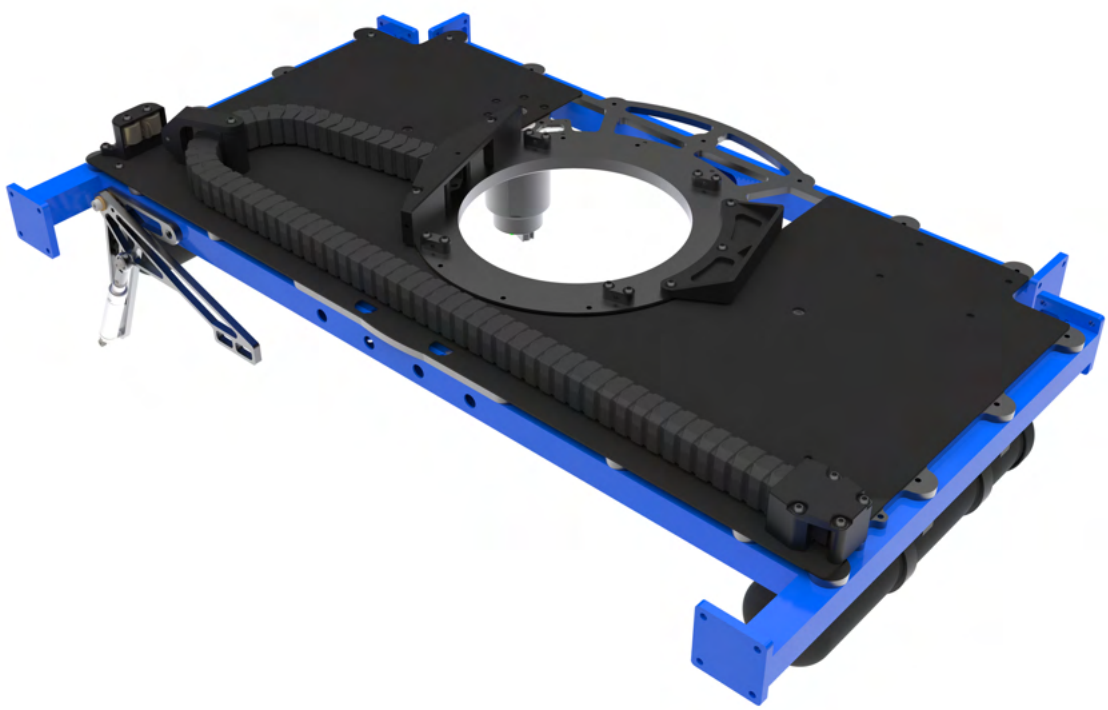
Serializer

- 22″ inner diameter circle maximizes space for the ball to enter without jamming
- 6″ central drum with 3″ long brushes spin balls
- Powered by 1 Falcon 500 with a 2.5:1 belted reduction
- Ejects balls into feeder in ~2 seconds
- Pneumatically actuated polycarbonate ramp raises balls into feeder rollers

Feeder

- Left-right rollers individually powered by 2 Falcon 500 motors via 0.333:1 belted reduction
- Front-back passive rollers center balls as they enter the shooter

SUPERSTRUCTURE



The turret sits above the serializer and rotates the shooter so that the robot can quickly score balls from nearly any orientation. It is powered by a Falcon 500 and uses a horizontal bidirectional IGUS chain for wire management.

Turret

- 51.4:1 geared reduction from 1 Falcon 500 motor
- Capable of ± 170° of rotation
- 10.5″ OD 10″ ID primary bearing allows balls to pass through into Shooter
- 2 hall effect sensors limit motion of turret and one hall effect sensor centers position of turret

Wire Management

- Bidirectional IGUS chain contrains and route wires to the turret
- Constant force springs create tension on the chain to constrain its path of travel

Chock

- Pneumatically actuated wall stops balls from circulating
- Allows balls to accumulate under turret, clearing space for balls to enter from intake

SHOOTER

The shooter utilizes dual-flywheels with an adjustable hood angle to enable shooting from a majority of the field locations. A Limelight camera on top vision tracks retro-reflective tape on the goal to aim the turret, control the hood angle, and adjust the flywheel speed.

Dual-Flywheel Shooter

- Powered by 2 Falcon 500 motors via a 1:1 belt reduction
- Lower flywheels are 4” diameter neoprene
- Upper flywheel is 2.5” diameter neoprene
- Short enough to pass under a trench

Adjustable Hood

- Enables shooting release angles from 45° to 70° above horizontal
- Powered by 1 Falcon 500 motor via 310.5:1 reduction and a 3D printed rack gear
- Hall effect sensor zeroes hood angular position

WOF MECHANISM

The “Wheel of Fortune” (WOF) Mechanism is a pneumatically deployed arm with a wheel and color sensor at the top to manipulate the Control Panel.

WOF Mechanism

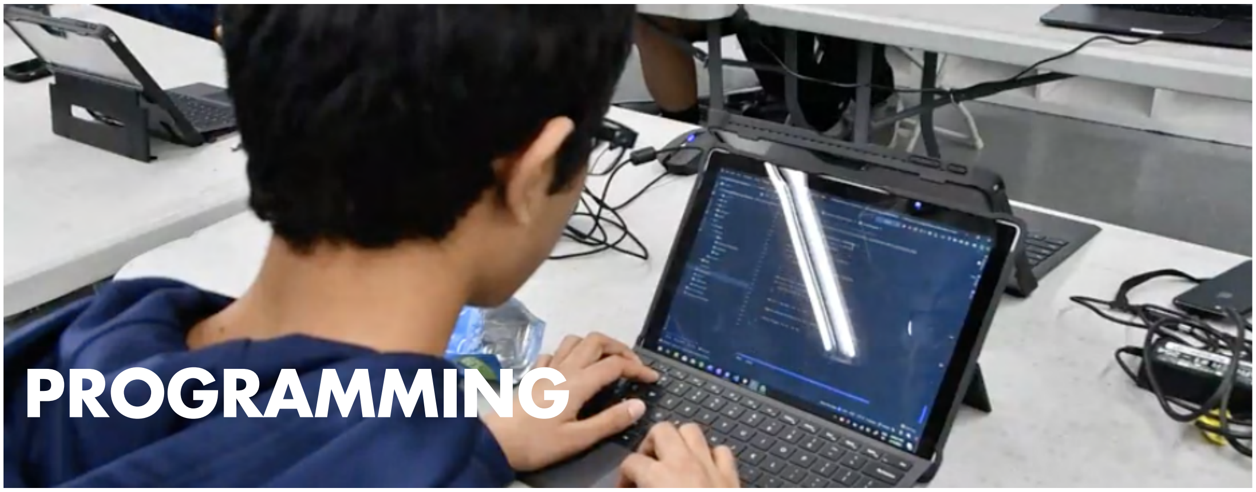
- 15” long arm stows below the shooter release point
- Actuated by a 9/16” Bore 4” Stroke Pneumatic Cylinder
- Steel lanyard (not pictured) absorb force in the case of a crash
- 3” 60A flex wheel powered by Falcon 500 with a 3.13:1 belted reduction
- 2 REV color sensors (removed from housing to make assembly compact) offset by 15 determine color even on edges of two colors
- Sensor wires plumbed through 1x1 tube for a clean look

CLIMBER

The climber is made of two 3 stage sets of nested tubes that deploy via springs and pnuematic cylinders. They climb down through a geared Powered Take Off with the drive gearbox to pull the robot up.

Climber

- Nested 1/16" wall sqaure tubes (2", 1.75", 1.5", 1.25") with 1/16" thick PTFE sliders
- Extends up to 82" above the ground
- Deploys the first stage with 3/4" bore, 18" stroke, cylinder and second and third stages with 1" OD compression springs inside the tubes
- 2mm Dyneema rope retracts climber
- Powered by Falcon 500s Drive gearbox via a 9.88:1 gear reduction to retract in under 2 seconds
- Dog shifter in Drive gearbox acts as a break to hold the robot up after the match and during a match to retain compression spring load



PROGRAMMING

Autonomous Code

The robot smoothly follows precalculated trajectories autonomously during the Autonomous Period through the use of a state-space controller, which controls the velocity and acceleration of the robot's travel.

Robot Position Estimator

- Drivetrain encoders and gyro integrate the robot's position on the field over time
- Field-relative positioning through non-linear state estimation

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
- Results in smoother paths and more reliable tracking than our Adaptive Pure Pursuit controller

Driving Controller

- Utilizes advanced feedforward command generation based on motor characterizations to produce the necessary velocities and accelerations to follow the trajectory
- Uses a nonlinear state-space feedback controller (RAMSETE) to account for position error

Vision

A Limelight 2+ camera provides information about vision targets to automatically align the turret and hood, and determine the flywheel speed to shoot and score balls quickly and accurately.

Target Tracking

- Uses known height of targets along with the corner data sent by the Limelight to calculate the yaw angle from the robot to the target and align the turret to face the goal

Vision Cont.

- Goal trackers let the robot remember the position of a target even if it can't be seen anymore and smooth the target's position to account for noise and error in the camera

Scoring with Vision

- Uses the distance to the target to interpolate on pre-tuned treemaps to determine the shooter and hood setpoints

Teleop Code

The various subsystems are controlled via state machines to prevent undesired actions, with a superstructure state machine controlling the overall robot actions

Field-Relative Turret

- Allows the drivers to accurately hint the turret towards the target if necessary
- Uses the gyro heading to turn to field-oriented cardinal cardinal directions to ensure the camera on the turret can see the vision target

Shooting Controls

- Allows the operator to select between the outer port and inner port
- Gives the operator the option to adjust shots to be higher or lower, based on the quality of balls
  and accelerations to follow the trajectory

Tuning 11-Ball Auto