JACK in the BOT
FRC TEAM 2910

PHANTOM

2022-2023
Technical-Binder

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Game Analysis and Strategy

Ranking Point Analysis

<u>Link:</u>

In order to reliably secure the 5 links required for the Link ranking point, our robot must cycle as quickly as possible. Initial analysis shows that for practical purposes no single robot can, under normal match conditions, guarantee the link RP. However, a highly optimized cycle, wherein for practical purposes game piece collection and scoring is instant, can require as low as 2-3 cycles from alliance partners.

<u>Balance:</u>

In order to most reliably secure the balance charge point, we need to be able to balance during auto, as this can reduce the amount of teams needed to balance during endgame, simplifying the process and making us less reliant on robot size, as well as possibly giving our robot extra time to cycle.

<u>Priority List:</u>

Below is a copy of our post-kickoff priority list. The list is organized into 3 categories based on cycle timing, auto structure, and our overall team goals.

Must Have	Nice to Have	No
Omnidirectional Movement (Swerve, Fast)	Cone Intake (Any orientation)	Direct Acceptance
Score all Levels (Cones & Cubes) (<= 1 sec)	Traverse Charging Station at Speed	Multi Piece Handling
Balance Charging Station (Auto & Teleop) - w/Buddy		
Pick up cube from the ground		
~5 sec auto cycles		
"Touch it, own it" intake - Cubes - Upright Cones (Floor & Portal)		
Triple Climb		
Immovable on command		
Traverse Charging Station		

Interesting
Off Power Station Balancing
Side Climbing

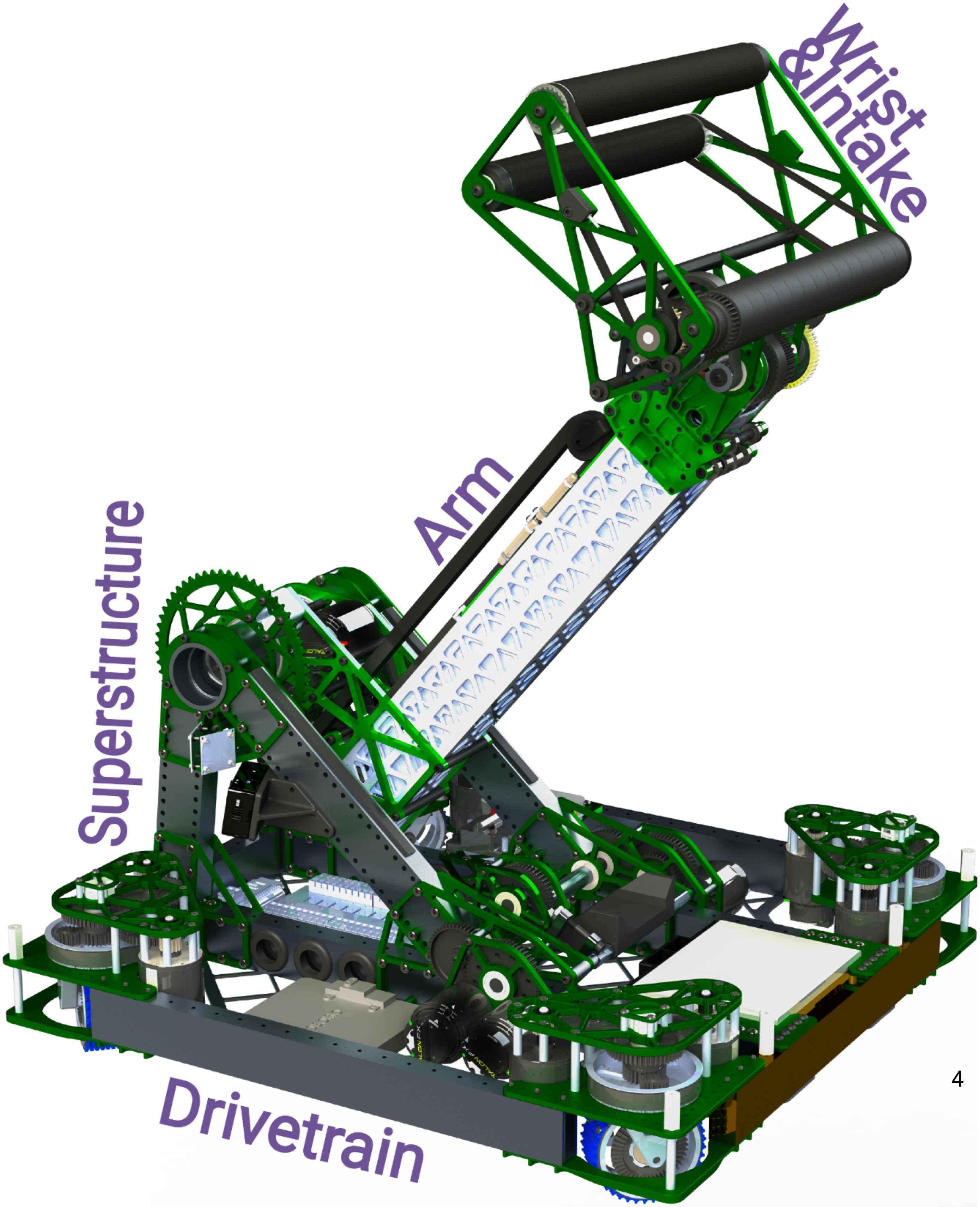
	Auto Score Cycle (2x)	
	Time (Sec.)	Action
	2	Exit Community Area
	0	Acquisition (Gamepiece)
	2	Return
	1	Score Second
Total	5	5 actions

Auto Structure		
Time (Sec)	Action	Repetitions
1	Quick Score	1
10	Score Cycle	2
TBD	Balance	TBD

Robot Requirements

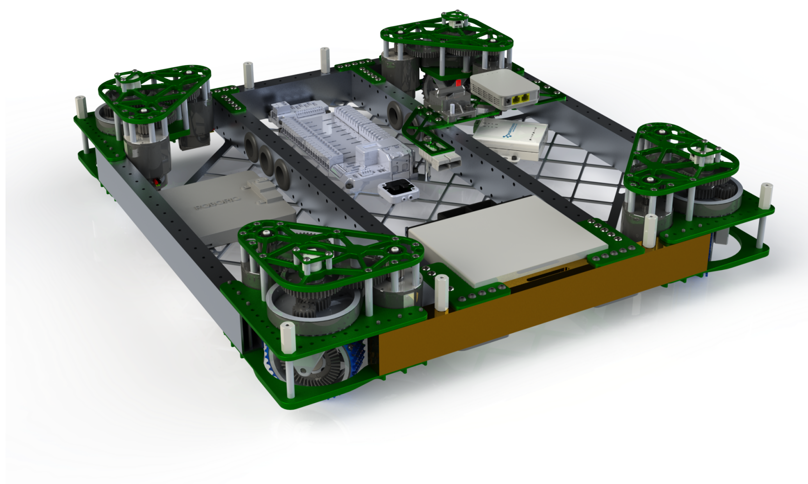
General	Drivetrain	Intake	Lifter
Low center of mass	Omnidirectional Movement (Swerve, Fast)	On-Contact Intake	Able to travel from ground to portal & all levels (< 1 second)
Subsystems can retract into frame perimeter post-deployment	~5 sec auto cycles	Orientation Independent Cubes	Can score at all levels from known position autonomously
Start match w/gampiece	Immovable on command	Upright Cones	Outtake/placement orientation results in > 95% success rate
Balance on Charge Station	Traverse Charge Station - 11 degree ramp - Any direction of travel - Solo balance (< 3 seconds)	Multiple Levels (Portal or Ground-Level)	Able to withstand full robot weight after falling over
	Travel across the field grid to portal & over charge station so that it is faster than going around	Deployable & usable while in motion (Full speed)	Replaceability: - Replaceable but no specific timeframe
		Deployable & usable while robot is stopped	
		Able to intake both cones and cubes next to wall	
		Able to outtake while moving	
		Reliability: - Able to withstand collisions (walls, robots,etc.) w/o dropping gampiece - Able to withstand collisions regardless of side - Does not let go when disabled - Durable, able to withstand multiple (entire competitions worth of) full speed collisions with field hazards (robots, walls) while extended	
		Replaceability: - Easy to swap - < 8 min turnaround	

Robot Design



Drivetrain

Keeping with tradition, our drivetrain utilizes a swerve drive-base, its maneuverability and speed complimenting the robot's size.

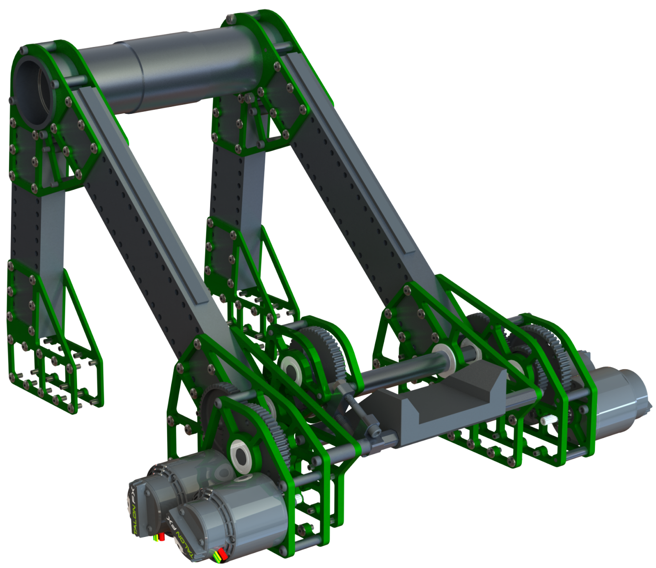


- **Primary Requirements:**
    - Able to move omni-drectionally without sacrificing precision and stability
    - Electronics mounting

- **Chassis**
    - Swerve Drive Specialties Mk4i Swerve Modules
        - 23 ft/sec free speed, custom adaptor for 18T motor pinion combined with L3 ratio gears
        - Corner bias modules increases robot stability
        - Structurally robust, physically compact, and easy to maintain
    - Solid brass front crossbar (~10lbs) lowers and shifts CG forward to counterbalance the arm when scoring

Superstructure

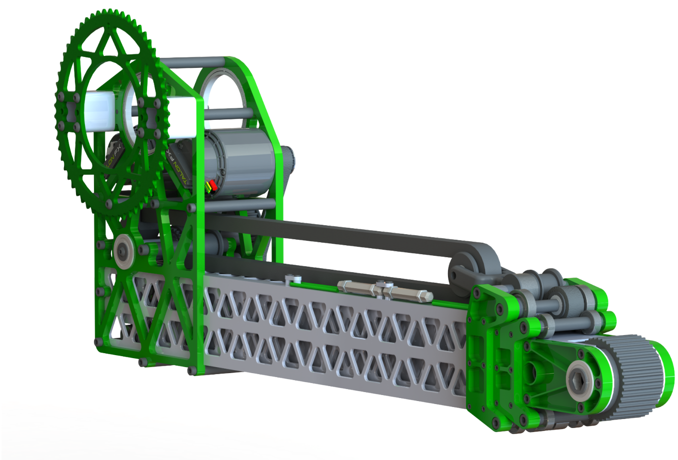
The structure provides a dead axle for the arm to rotate around. Keeping with the theming of a highly integrated and compact design, our superstructure is combined with the gearbox that drives our arm and a cradle to soften impacts.



- **Primary Requirements:**
  - Must be capable of <1 second arm deployment
  - Must maintain low center of gravity
  - Must allow for accurate arm rotation control
  - Must include provisions for camera mounting and LED lights

- **Frame Structure**
  - Riveted custom gussets and box tube frame for rigidity and lightness
  - Hole patterns for mounting cameras, LED strips attached to tops of tubes
  - Lower gusset plates integrated with arm cradle and arm gearbox
- **Gearbox**
  - Driven by four Falcon 500s at a 111.88:1 gear ratio
  - ANSI #35 pre-stretched chain powers final sprocket reduction
  - Uses a screw tensioned swing-arm third stage for chain tensioning
    - Enables faster and more precise software control by improving system stiffness
- **Cradle**
  - Designed to reduce load on pivot from collisions when arm is in ground collect and storage positions
  - Hard stop for homing arm encoders and soft the impact of repeated arm usage
- **Pivot Axle**
  - Large dead axle increases structure stiffness
  - Held together by two custom round end plugs
  - Stepped plug design ensures concentricity and prevents gusset buckling
  - Allows the entire arm assembly to be removed and swapped with a single bolt

Arm

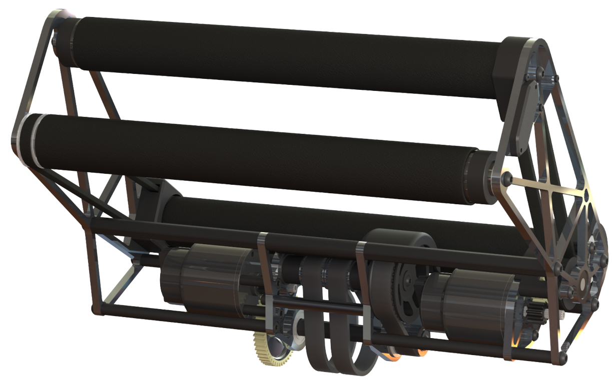


The core system of our robot, our arm, is designed to be able to take our intake from a fully stowed configuration to scoring behind the robot in half a second.

- **Primary Requirements:**
  - Able to get from Stowed to Portal Shelf and All Scoring Levels in <1 second.
  - Able to withstand significant forces including side-on collision while extended

- **Pivot**
  - Offset pivot allows for dead axle design for improved stiffness and extremely low CG in storage configuration, while aiding reach in scoring configurations
  - Two 2.5” ID X-contact bearings provide a very rigid and robust pivot around the dead axle
  - Bearings are captured between counterbores in pivot plates and a center shoulder on the pivot axle which locates the arm on the robot centerline
- **Elevator-Arm With Cascade Rigging**
  - A dual Falcon 500 gearbox with a 4.27:1 Reduction allows the arm to be fully extended in < 0.2 seconds
  - The two outer stages made of 1/8" thick pocketed aluminum tubing and an innerstage of 1/16" thick aluminum tubing provide an excellent balance between strength, stiffness and weight
  - In order to optimize size and weight the arm is created with 3”, 2.5” and 2” aluminum box tubing
    - The tubes are shifted 0.0625” downward relative to their preceding stage to provide the required room for cascade rigging
- **Wire Management**
  - Monodirectional energy chain tensioned by dual constant force springs feeds wires axially through the back of the extension

Wrist and Intake



Keeping with the objective of a highly integrated and compact design, our wrist is combined with our intake to allow for pivoting about the arm and allowing for 180 degrees of articulation while also being able to intake both game pieces from any orientation and any level, while weighing only 7.5lbs.

- **Primary Requirements:**
  - As light as possible to enable fast arm movement
  - Able to intake both game pieces from double substations as well as from the floor (including upright or tipped cones)
  - Be able to outtake onto any level on the grid

<u>Intake</u>

- **Roller Design**
  - Custom rollers are dead axle to minimize weight and add structural rigidity
  - 3D printed end caps with integrated pulley, bonded into a thin wall polycarbonate tube results in 0.5lbs weight per roller
  - Thin but grippy silicone tubing stretched over the roller
  - Needle bearings on thin wall steel dead axles with thrust shims
  - Lower roller is gear powered, upper rollers are belt powered with 3D printed pulleys
- **Sensor Integration**
  - A single Time-of-Flight sensor located near the cone rollers is used to detect the lateral position of the cone in the intake for automated scoring alignment

<u>Wrist</u>

- **Pivot**
  - Custom 3D-printed pulley fixed to arm
  - Mechanism and driving gearbox rotates around pivot
- **Gearbox**
  - 39.51:1 gear reduction with a theoretical travel time of 0.2 seconds
  - Reverted gear-train allows for a more compact gearbox without sacrificing overall efficiency or weight
  - Motors packaged close to the pivot to reduce required torque and rotational inertia

Software

Team 2910 software ensures that the mechanisms of our robot are controlled consistently and effectively.

AdvantageKit/AdvantageScope

- This year Team 2910 used AdvantageKit/AdvantageScope, software developed by Team 6328 Mechanical Advantage. AdvantageKit is a framework which can be integrated into robot projects to allow for logging of data from hardware components as well as variables defined by the user.
- With this logging framework, we use AdvantageScope to view these variables in real time while connected to the robot, in simulation, or from logfiles which we can download from the roboRIO.
- This software allowed us to test and develop lots of code during build season before robot bring-up, as well as debug efficiently when we had a physical robot.

Arm and Intake

- As a software team, we visualize what designers see as the “arm and wrist” as three variables: the angle of the arm mechanism itself, the extension of the arm, and the angle of the wrist/intake. We define our angles as being 0 when they are parallel to the ground, and we define the extension as the actual length of the arm (as opposed to the extension of the arm from some zero point).
- We focus our code around controlling these three variables. To ensure that the mechanism does not enter a game-illegal state, or enter a state which could damage where it may damage itself, we perform multiple checks which clamp the state if necessary.
- Once we have a legal state defined, we then pass those values on to the appropriate motors. We use MotionMagic to ensure smooth motion of the mechanism.

Operator Dashboard

- In order to manage our various arm states, we use Shuffleboard to create an interface for our operator. During a match, our driver is the only person who has physical control of the robot. However, the driver only has one button each for portal intaking, ground intaking and scoring.
- Using the dashboard, the operator toggles between which node and which piece we are scoring (as well as whether the cone is upright if we are ground intaking a cone) which are then passed into our code. When the driver presses one of the aforementioned triggers, the code returns the correct target state based on the data from the dashboard as well as which button has been pressed.

Vision

- We have 2 Arducams on either side of our superstructure. These are connected to an OrangePi processor. We use PhotonVision to interface with our vision data.
- To relocalize on the field, the robot uses a combination of wheel odometry and data the cameras get from the AprilTags.

Automated Scoring

- To initiate the automated scoring process, the driver simply presses the button to move the arm to the scoring pose then holds down the “auto-align” button. With the help of AprilTag data, the robot determines which node row is the closest and snaps to the correct y-position so that it is head-on with the correct node. If it somehow snaps to the wrong node, the operator can shift manually using buttons on the dashboard.
- Since cones do not always enter the intake at the same location, the robot uses data from a time-of-flight sensor mounted on the intake frame. The time-of-flight sensor determines how much the cone is offset relative to the robot, and passes that offset to the auto-align position.
- Once the robot is straight on, all the driver must do is drive back towards the grid until the robot is at the correct x-position. At this point the robot will auto-eject the piece. Auto-eject can be turned off or on on the operator dashboard.
- In case gyroscope data is inaccurate (due to high speed play during matches) the operator can offset the heading of the robot so that it approaches the grid straight on.

Autonomous

- To build our autonomous sequences this year, we used PathPlanner developed by Team 3015 Ranger Robotics. Rather than developing the whole sequence under one pathfile, the autonomous paths are structured such that each file is one scoring or intaking waypoint to another scoring or intaking (or charging station) waypoint.
- This allows for us to create our own custom methods which allow us to follow individual paths while performing synchronized arm and wrist movement. When brought together sequentially, these methods form a full autonomous sequence. Overall, the system improves modularity and creates an environment for quicker, cleaner development.

Other features

- In order to run the same code on our competition and practice bots, we developed some simple configuration logic which called the appropriate constants based on the MAC address of each robot.
- Our robot features two physical buttons which allow us to home the arm to its zero position, then toggle between brake and coast mode on the arm motors. These are used when setting up the robot before each match so the arm is zeroed and can be moved up to be ready to score the first piece.
- LEDs on the superstructure have multiple uses. While disabled, green LEDs communicate a homed arm while red LEDs indicate not homed. While enabled, yellow LEDs communicate cones to the human player while purple LEDs communicate cubes. The game piece is selected by the operator on the operator dashboard. While using auto-align, LEDs flash white when the robot is in the correct scoring pose.