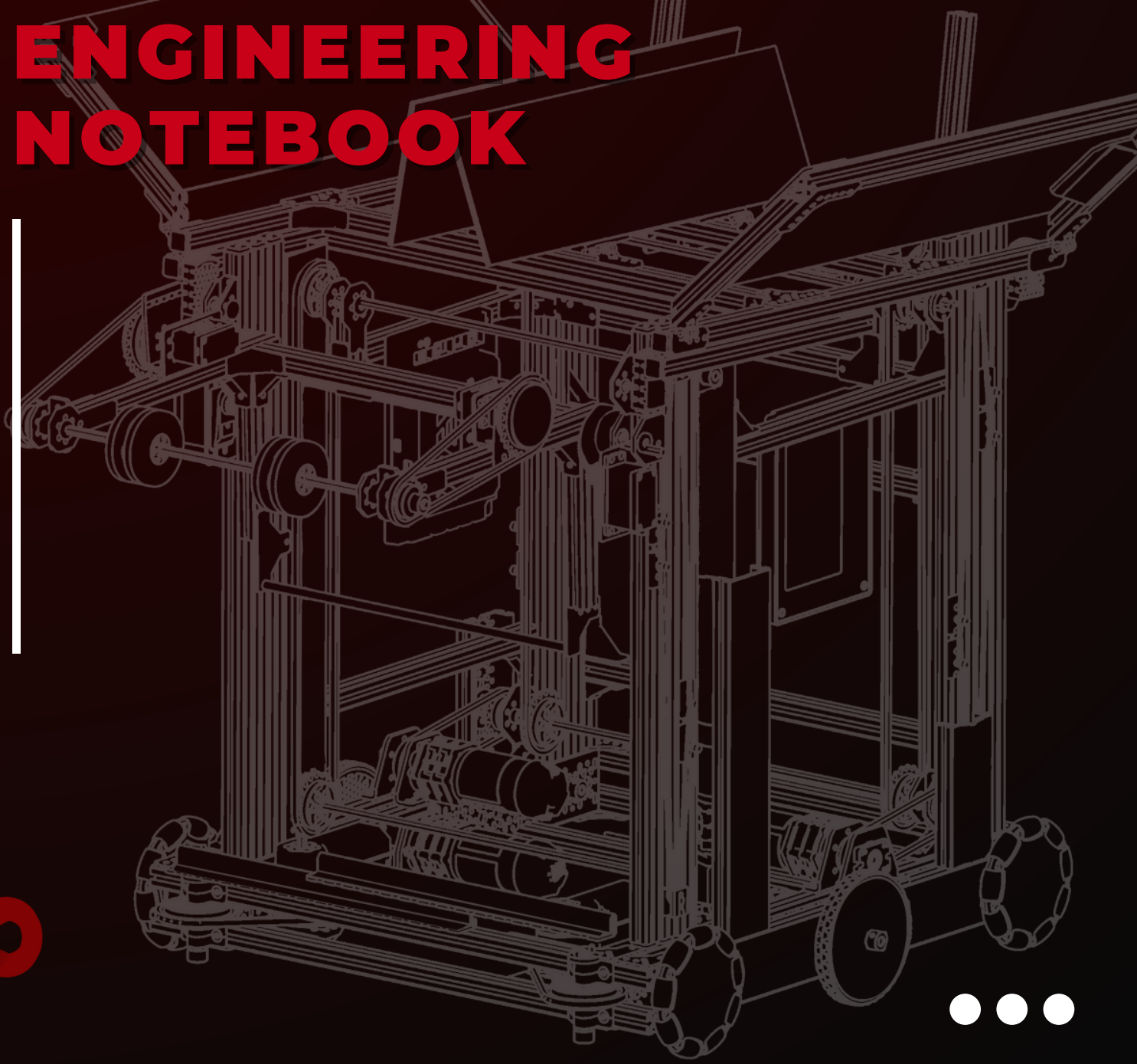
2024 FIRST Global Challenge Athens

TEAM PEOPLE'S REPUBLIC OF CHINA

ENGINEERING NOTEBOOK



Team Summary



We are the FGC Team People's Republic of China 2024, a group of thirteen passionate and dedicated students from various high schools in Beijing. Our team is composed of members from different FTC and FRC teams. Our team is led by several experienced mentors who encourage us to face challenges with determination and innovation.

Our team members have varying levels of expertise in engineering and programming. However, we believe that each team member has their unique talents and perspective. Through effective collaboration and communication, we are confident that we can successfully achieve our goals.



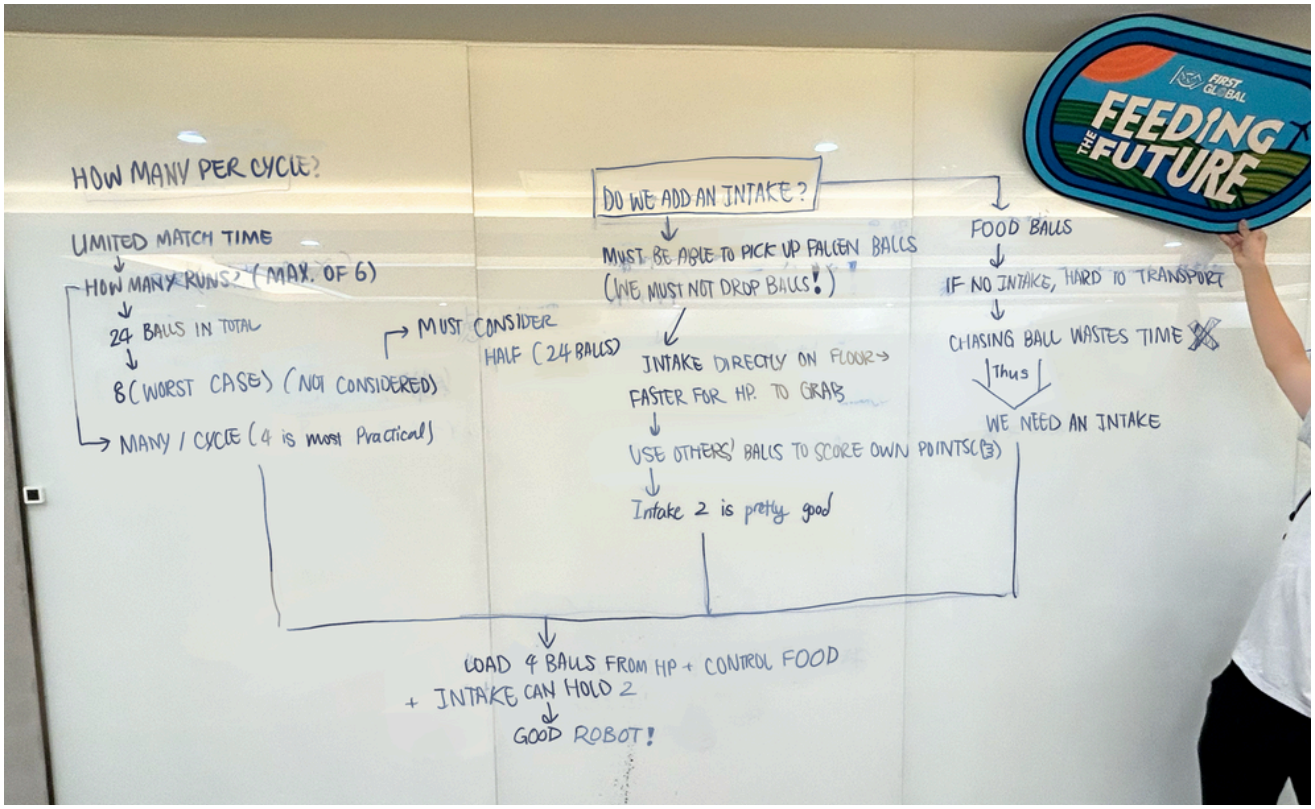


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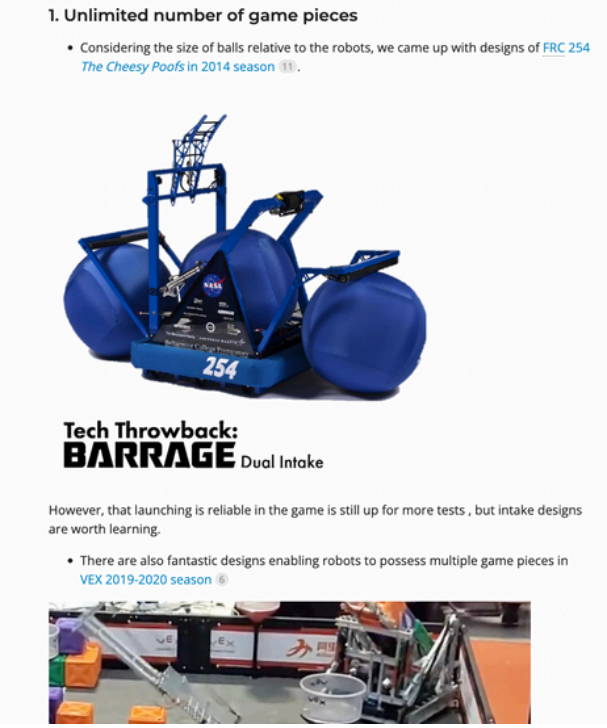
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Season Analysis

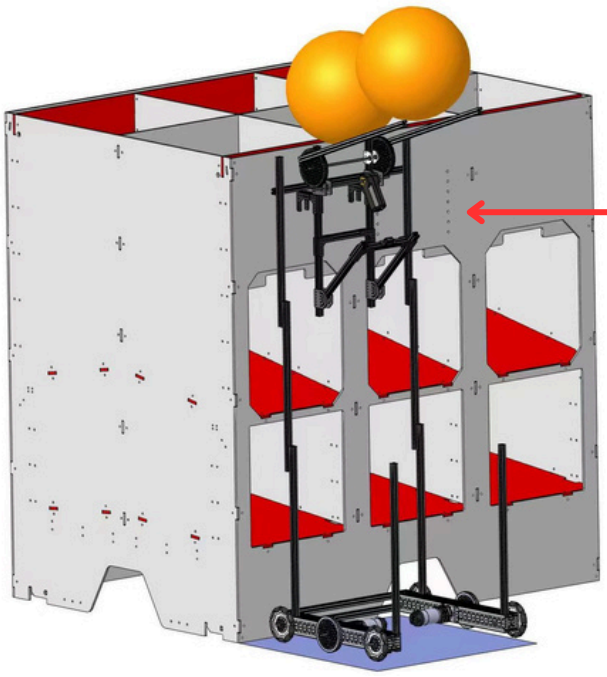
We immediately analyzed this year's FGC game when the rules came out. After realizing how large the ball and Nexus Goals are, we concluded that the robot's top priority is to be able to be **quickly loaded by the human player**, **drive to the Nexus Goals**, and **put Energy and Water into the goals as precisely as possible**. After a series of discussions and review of previous robots in FTC, FRC, and VEX, we decided to use vertical linear slides to lift the balls to the height of the Nexus Goals, while designing a ball storage that can hold as many Water and Energy balls as possible. In addition, we also saw the need to design an intake to **hold and carry Food balls back to the human player areas** and **pick up Energy and Water balls that other teams accidentally dropped**.



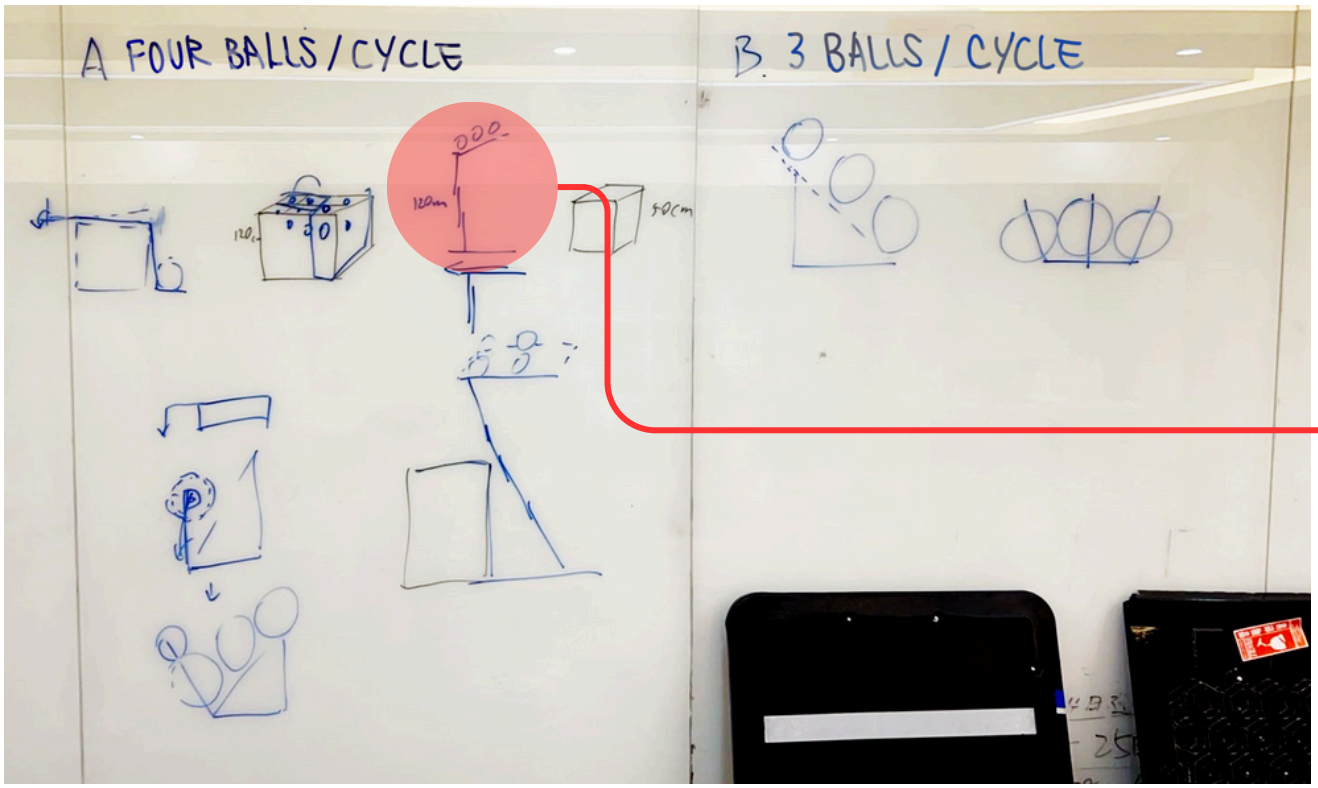
Planning



Above: A few initial sources of inspiration, which we compiled on ChiefDelphi to share with other global teams.

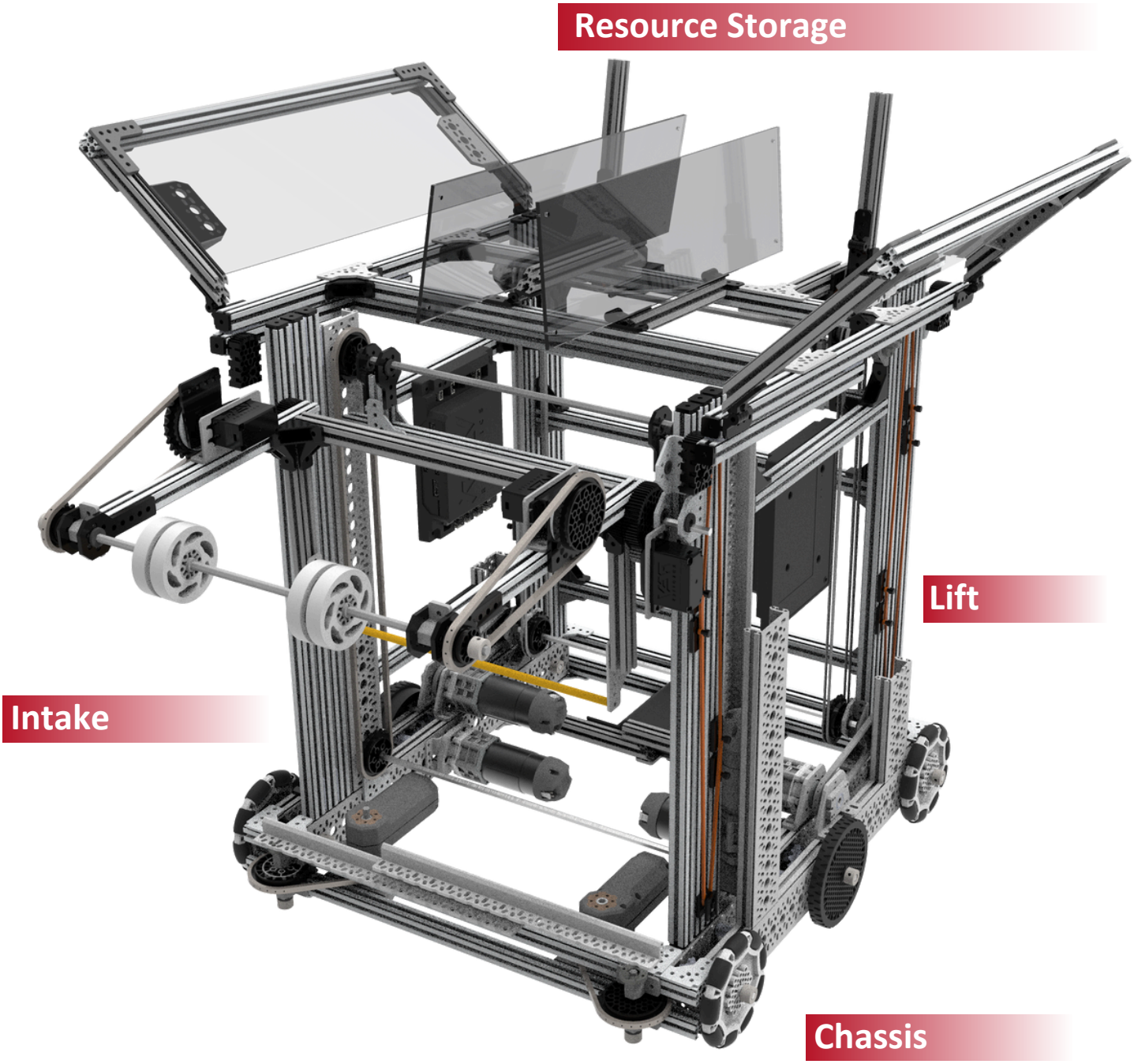


Above: an early CAD model of our robot



Above: Brainstorming how balls might be carried

Robot Overview

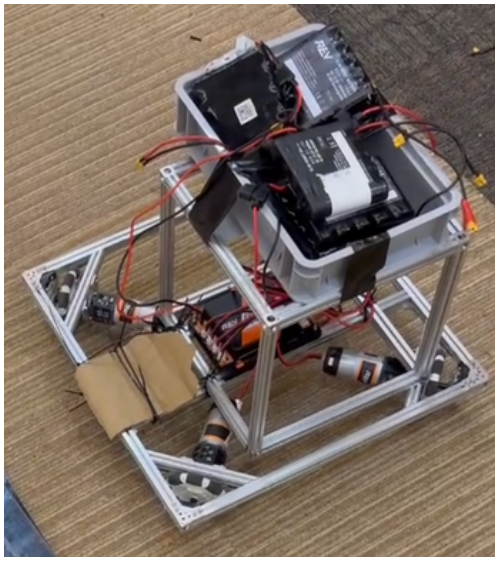


Chassis

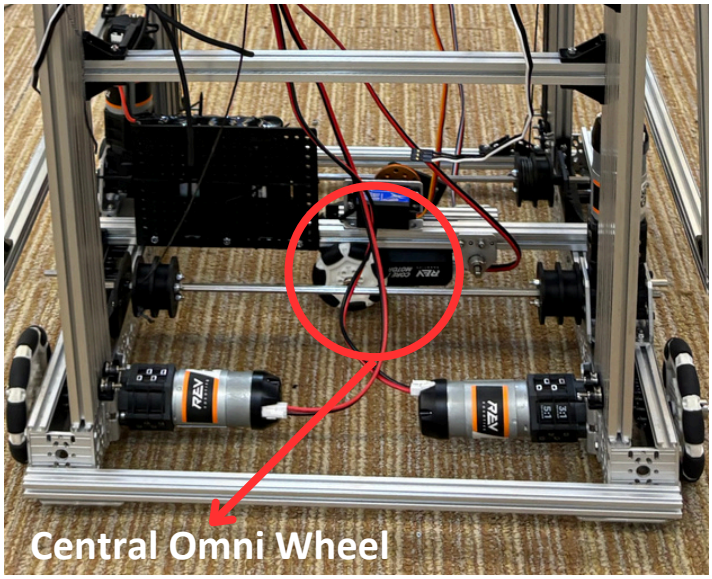
We pushed through two projects at the same time: we tested the superstructures of our robot entirely on a traditional tank drive, with four omni wheels on the four corners and two traction wheels placed in the middle, using two motors of a 15:1 transmission ratio as the power source. Meanwhile, we did two other tests on the chassis.

Test 1: Omnidirectional X-Drive

Due to the fact that this season has a high need for precision and speed, we tested a omnidirectional chassis, along with a camera that helps the chassis move with the identification of AprilTags. However, we found that the chassis had severe difficulties when maneuvering up the ramp. If the chassis was not exactly parallel to the ramp, two wheels would not be in contact with it, and the robot would begin to spin. As the coopetition bonus of the match, decided by the number of robots driving up the ramp, is a major factor affecting scoring, obstruction of completing the task pose a high risk to a robot's performance in the competition.



Test 2: Central Omni Wheel



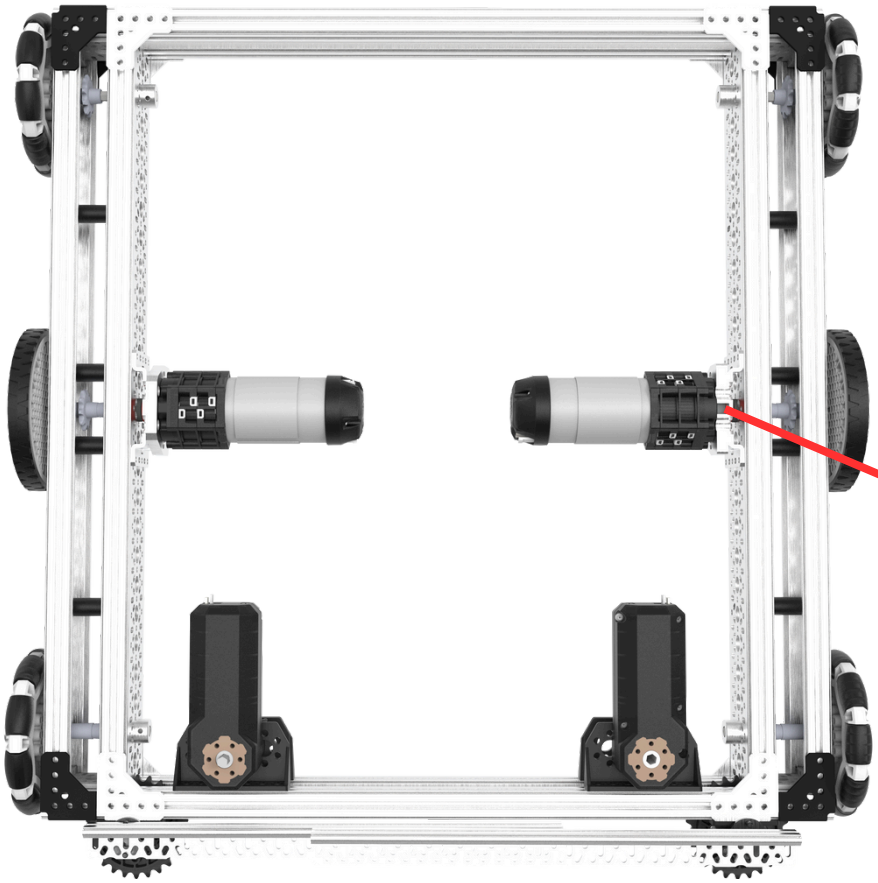
We also tried to build a chassis made of five omni wheels: two pairs on the side, and one in the center and placed sideways to allow the robot to move in that direction. Yet, we encountered several difficulties when testing that option. First, the robot required very special conditions to move sideways: the wheel must be pushed tightly to the ground to provide enough friction. We tried to use rubber bands to tie it toward the ground, but the bands would degenerate quickly, which added to the difficulty of robot maintenance. In addition, when the robot was going down the ramp, the wheel sometimes would interfere with the process, as the ramp's corner was higher than the four omni wheels on the outer side.

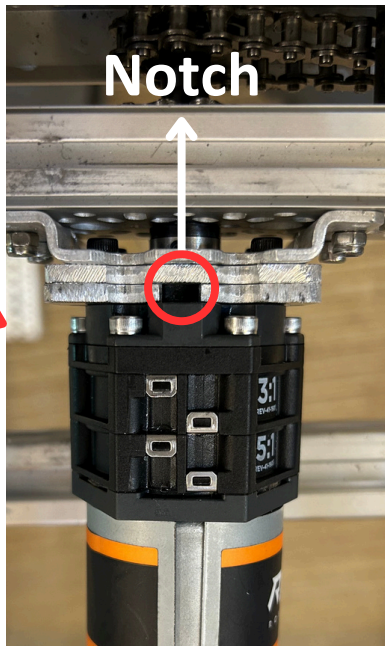
Chassis

Final Version

After weeks of rigorous testing, we eventually decided that the obstruction of going up the ramp caused by the Omnidirectional X-Drive is too severe to be acceptable, while the cost of maintaining the rubber bands of the Central Omni Wheel system is also too large. In addition, as tests of the superstructure were done on the tank drive, it turned out that the robot could also complete tasks efficiently without the ability to move sideways. Thus, we decided to use the traditional tank drive with a 15:1 transmission ratio.

Nevertheless, there was a serious problem regarding the loosening of the shaft of the center wheel due to the loosening of the set screws on the motor. To solve this problem, we added one more motor frame to make room for a shaft clip to be added between the C-channel and the motor. Another shaft clip was placed outside the wheel, making the shaft more stable. Moreover, a notch was created for easier fastening of the set screws.



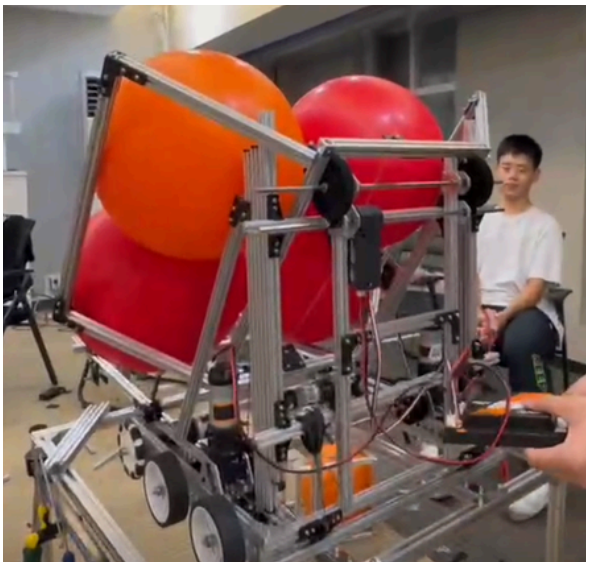


Superstructure

Iteration 1:

Lift

- The first iteration of our lift contained two 3-stage slides with a string-driven elevator mechanism.
- Even though this version successfully enabled us to score four balls at once, the maximum height was not high enough for scoring stably.



Resource Storage

- The first iteration of the storage bucket was placed at an incline, which caused interference with the sliding mechanism.
- The gears we used to pivot the ball storage at the top was also inconsistent. When we attempted to release the balls, the motor had to create a great deal of torque to tip the storage, which was too much for the plastic gear to withstand causing it to skip gears.
- A single gate was used to release the balls, but it only allowed the robot to release all four balls at once.
- Two aluminum extrusions were used to guide the balls; however, they could not prevent the balls from rubbing with each other, causing friction.
- Expandable panels were installed on the sides that increased the storage capacity of the robot. They could also be folded onto the top to ensure the robot did not exceed size limitations.

Iteration 2:

Lift

- For the second iteration, we changed the slide into a 4-stage continuous slide that was also driven by strings.
- After more rigorous testing, we discovered that the weight of the balls and the upper structure caused the elevator and upper structure to twist and shake as the robot moved and turned.

Resource Storage

- In the second version, we changed our pivoting mechanism to use a chain, with the motors propelling the chain drive below the storage, so that we can use shorter electrical wires for the motor, while providing more stability for the spinning mechanism.
- The side panels were redesigned to more sufficiently fold to the sides.

Superstructure

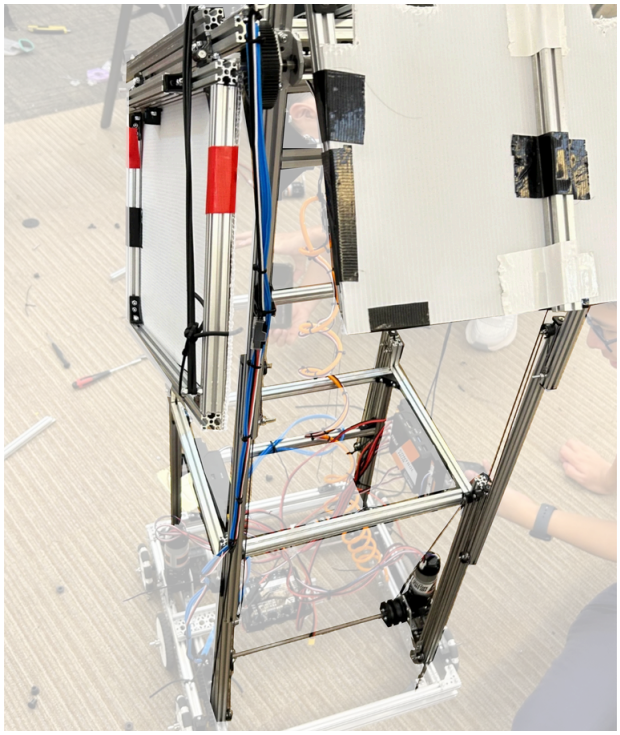
Iteration 3:

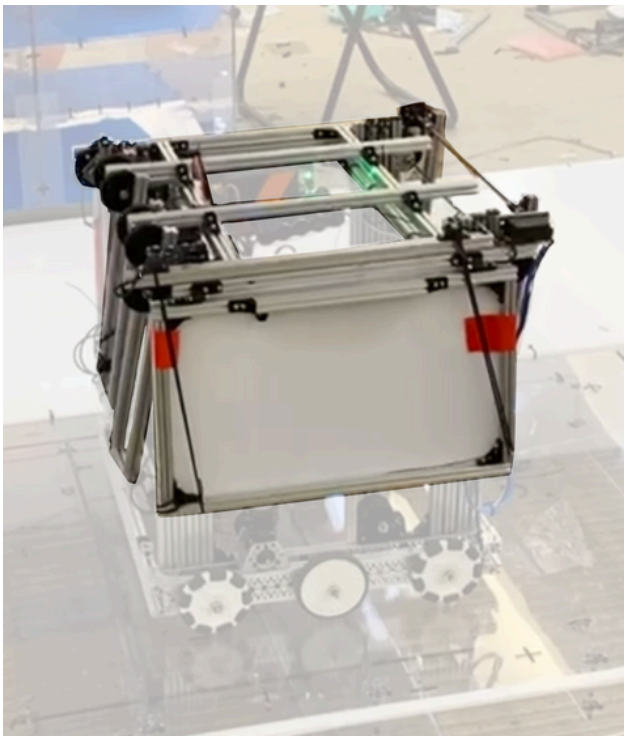
Lift

- In order to further increase stability, we changed from using two slides to four slides, operating in pairs of two. When one slider was more extended than the other, the storage at the top would tilt, allowing the robot to release the balls.
- This system had the advantage of not having motors at the top, eliminating the issue of motor wires being too short.
- However, the mechanism made use of REV's bearing blocks and v-groove bearings, which could not hold up to the stresses of testing the robot.

Resource Storage

- To ensure that the frame remained stable while the two pairs of slides were at different heights, an additional set of sliders made from 420mm extrusions was placed under the frame.
- This version also saw the addition of two front doors, which were chain-driven by two servos. These components were installed on the extrusions above the base, allowing for the individual release of balls. The rudder plate connected the servos through the motor frame, which significantly improved the system's ability to withstand tangential forces.



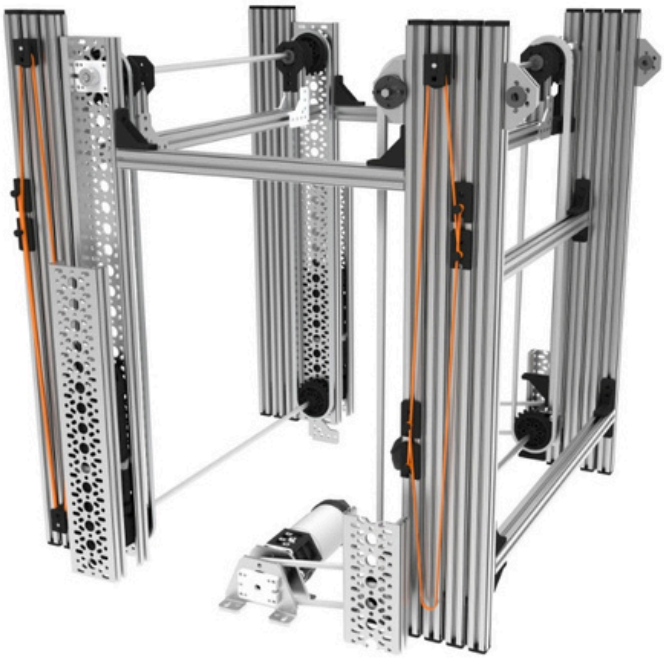


Superstructure

Iteration 4:

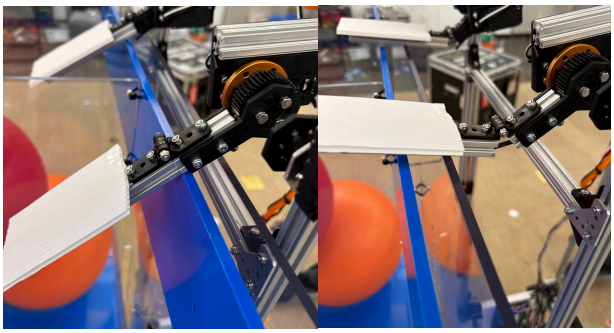
Lift

- Seeing as we did not have enough chains to power all four slides, we devised a hybrid system, with the first level of the slides powered by chain drives, while the rest of the levels are cascade slides powered by strings.
- This provides stability, as reverse winding is no longer needed for the cascade slides; besides, we also developed a way to fix strings onto the extrusions using parts cut from slider plates.
- Consequently, the strings do not break frequently, reducing maintenance frequency.



Resource Storage

- In the fourth version, the design focused on reducing excessive extrusions.
- The door servo was replaced with a direct-drive system, and the door's design was revised to a two-part system that passively folds upward, preventing damage to the servo.
- Corner brackets were added to increase the torque of the side panels.
- A structure (below) providing elasticity to the door is designed to prevent the door servos from breaking under a excessive tangential force



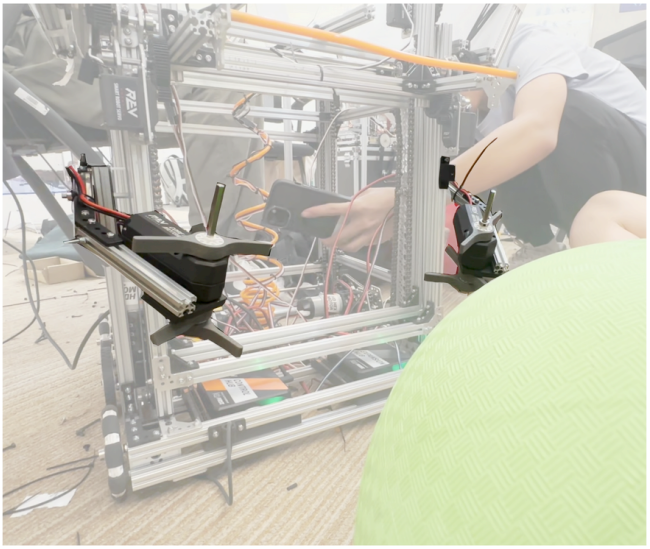


Intake

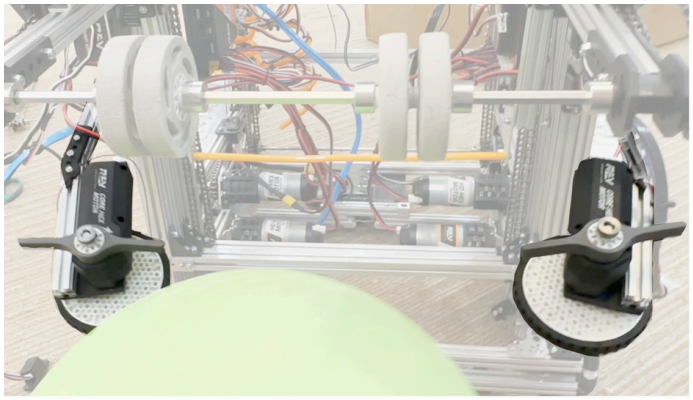
After we developed our second successful superstructure (the four-slider system), we found out that it is very likely that a team fails to release Energy and Water balls precisely and cause them to fall to the ground. Therefore, we decided to develop an intake system that can carry released Food balls as well as misplaced Water/Energy balls to the human player.

Iteration 1:

- The first version of the intake system consisted of two arms that are attached to the sides of the robot that could rotate up or down based on an axis. Their movement was restricted by two physical limits.
- The arms were held by rubber tubing in the back to ensure that it did not exceed size limitations when the robot was in its initial position.
- A motor was installed at the front of each arm that was attached to two intake flaps. When the flaps spun, balls could be taken in.



Iteration 2:



- The second version was largely similar to the first. We noticed that the intake flaps of the first version did not provide enough friction, so we switched the spinning mechanism to use a traction wheel instead.
- However, even though the friction of the traction wheels was sufficient, they would cause the arms to bend, which also led to the failure of the intake system.

Intake

Iteration 3:

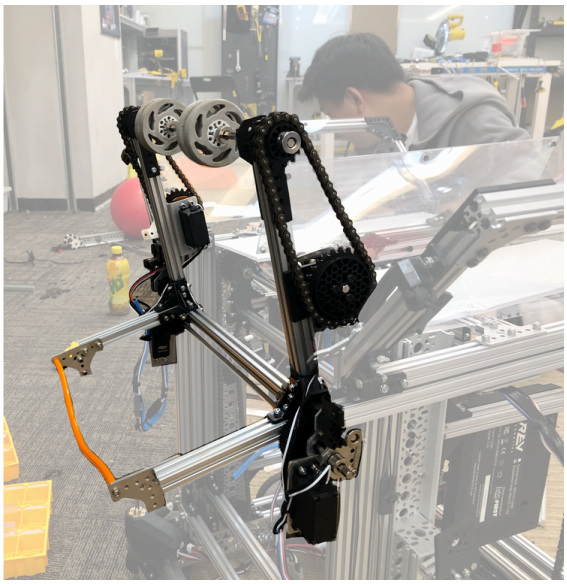
Lower Intake Structure



- For the final version, we decided to change the grabbing structure to two channels with a slight height difference. We place the motors at the front of the chassis and use a chain drive so that the arms of the intake could rotate within a certain range.
- Additionally, we added two color sensors so that the intake closes on its own when it senses a ball. This allows the robot to intake balls even when the driver's vision is blocked. The two halves of C-channels could also produce a deformation in the ball to let it leave the ground, enabling the lower intake structure to carry balls on its own.

Upper Intake Structure

- We also added a structure on top of the intake that scoops the balls upward and carries it securely once the ball is grabbed by the arms at the base.
- One half of the structure consists of a roller with rubber wheels, powered by two servos. The other side uses a piece of tubing to catch the ball, much like a net.
- Both elements together can turn according to an axis, which is also powered by two servos.
- This allows the robot to intake up to two balls, which matches the robot's ability to place four Water and Energy balls at once.

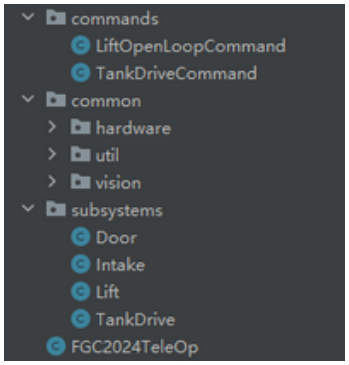




Programming

FRC-Style Template Command and Subsystem

By separating the robot to several functions and parts, we made a control system that is easier for debugging, reading code, and driving the robot. Specifically, this system creates a clear separation between the command part and hardware part, so we can test each part in order without worrying about their interactions.



Statemachine Subsystems

We used Statemachine in our Intake and Lift subsystems to simplify the complicated logic of different actions and prevent possible conflict. For example, due to the various height of Nexus Goals, the lift system is designed with 4 lift states. Each state (ORIGIN, LOW, MID, HIGH) has predefined actions or motor positions. In addition, we defined the state of intake as HOLDING, RISING and FALLING, accompanied with door state, making the logic intake action clearer.

Drive Power Rate Limiter

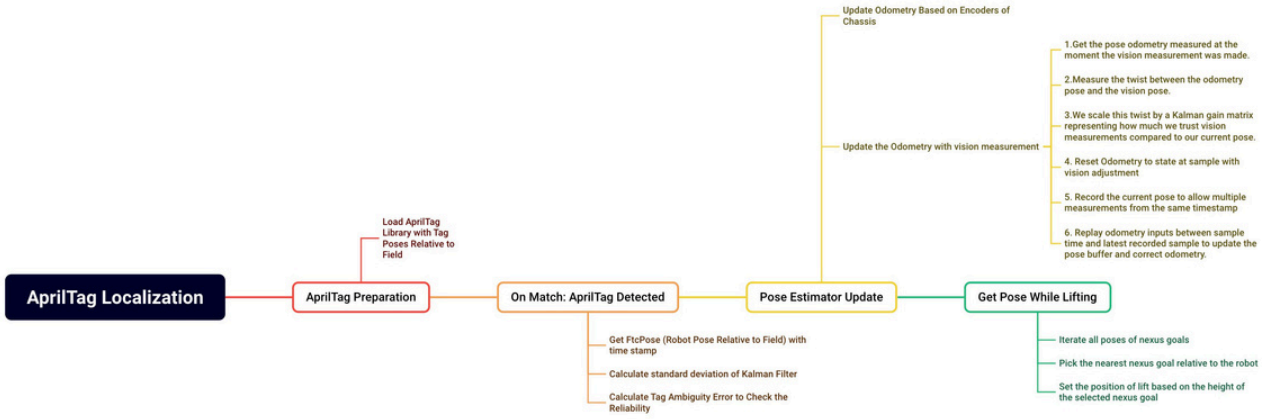
The rate limiter limits how fast a value can change over time, preventing sudden spikes or drops in input values. In the class of Rate Limiter, we have a timer to calculate the time interval between two samples, and then restrict the increased value by the limits we previously set to make the value vs. time relationship as a linear function. Thus, the acceleration and deceleration of robot due to sudden gamepad movements are limited to a specific range, preventing it from tipping over.

Programming

Vision & Position Calibration

We have utilized the location of the AprilTags to drive the robot at the desired position. By adding Feeding The Future AprilTag Package into the program, we can access the AprilTagDetection including angle offsets as well as camera distance to the AprilTag. Then, we used two PIDF controllers to drive the chassis to approach the set point to help our lift mechanism to release balls more stably.

The image below is the program structure we designed to implement the field-relative robot localization based on AprilTags. We tested a Kalman Filter to decrease the noise brought by AprilTag ambiguity so that we could derive field-relative robot pose by merely capturing AprilTag video stream. However, restricted by the low accuracy of REV wheels and the encoders embedded in the chassis motors, we were unable to combine the pose derived from drive-base pose estimator and that from vision pose estimator, so the field-relative robot pose is not precise enough to support more advanced usages. We are optimizing our program to decrease the negative effects brought by the hardware to make the pose estimator more stable.



Intake with Touch and Color Sensors

Our robot has the ability to intake 1 ball from ground. However, the drivers do not have a good view of the front of the robot. For this reason, we decided to add 2 color sensors on each side of the intake. When the color sensors detect a ball that has color, the intake will close automatically. Moreover, 2 touch sensors are used to prevent collision between the intake system and lift system, so drivers can control the robot more easily.

Publicity & Outreach

Throughout the season, Team China has done our best to embody the spirit of Gracious Professionalism in our interactions with others.

Meetings with other teams

Team China actively held and participated in online meetings with more than 20 other FIRST Global teams to exchange our cultures and knowledge.





CAD and Tech File Sharing

We have uploaded our past robots' CAD models to GrabCAD and Onshape so that other teams may reference them. We have been eager to help out with the mechanical aspects of several teams who have reached out to us for assistance.

Outreach Toward Public Figures

We reached out to several Chinese Olympic athletes, introduced FGC to them, and earned their support in the competition. We also successfully invited Chinese ambassadorial representatives to spectate in Athens.







Community Service

In our capacity as an FGC team, we have also hosted events aimed toward developing the skills of students new to FTC and FRC.

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